VOLUME XXXVIII NUMBER 8 WHOLE NUMBER 337

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

EDITOR, C. A. CHANT ASSISTANT EDITOR, F. S. HOGG

David Dunlap Observatory
Richmond Hill P.O., Ont.

ASSOCIATE EDITORS

R. MELDRUM STEWART
Dominion Astronomer
Ottawa

J. A. PEARCE
Head Astronomer
Dominion Astrophysical Observatory
Victoria, B.C.

J. PATTERSON
Controller of the Meteorological Service of Canada, Toronto

PUBLISHED MONTHLY
(Ten numbers per year)

October, 1944

PRINTED FOR THE SOCIETY
TORONTO: 198 COLLEGE ST.

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

VOL. XXXVIII, No. 8 OCTOBER, 1944 WHOLE No. 337

Articles PAGE

The Quebec Centre of the Royal Astronomical Society of Canada (with Plates VI, VII) ..... *Paul H. Nadeau* 313

Request for Auroral Observations 320

Occultations: their Prediction, Observation and Reduction (continued from page 294) ..... *H. Boyd Brydon* 321

Absorption Line Intensities and Spectral Types for the O Stars ..... *R. M. Petrie* 337

Review of Publications

Rockets—The Future of Travel beyond the Stratosphere, by Willy Ley ..... *C.A.C.* 349

Notes and Queries

Death of Philip Fox (*C.A.C.*); Can Anyone Explain? (*C.A.C.*); Occultations of Planets by the Moon, by W. H. Haas (*C.A.C.*); Is Washington approaching London? (*C.A.C.*) 350

Meetings of the Society

At Vancouver—At Edmonton—At Toronto 354

Upon request, made previous to publication of article, contributors will be supplied free with twenty-five copies of the sheets containing the article attached to a printed cover.

Extra copies about as follows:

	4 pp.	8 pp.	12 pp.	16 pp.	20 pp.	24 pp.
50 copies....	$3 50	$5 50	$9 50	$10 00	$13 00	$16 00
100 copies....	4 00	7 00	10 00	11 00	14 00	18 00
200 copies....	4 50	8 00	11 00	12 00	15 50	20 00

Covers, extra, 50 copies, $1.50; 100 copies, $2.00; 200 copies, $2.50.

Address of Editors: David Dunlap Observatory, Richmond Hill, Ont.

Business correspondence, remittances, etc., should be addressed to J. H. Horning, Treasurer of the Society, 198 College Street, Toronto 2B, Ontario.

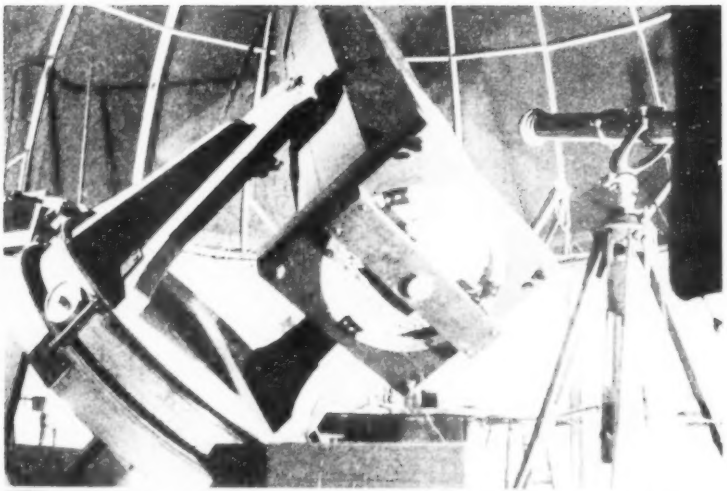
$2.00 per annum. Single numbers, 25 cents.

Subscription to the JOURNAL is included in membership fee.

Visitors to Toronto who wish to get in touch with the Society are invited to telephone:

General Secretary—Mr. E. J. A. Kennedy, WA. 6363.
Assistant Secretary—Miss E. M. Budd, RA. 7186 (Residence).
At Office, 198 College St.: 10-12 a.m.—Mon., Tues., Sat.; 2-5 p.m.—Mon., Tues., Wed., Thur., Fri.; 7-9 p.m., Thur.

PRINTED IN CANADA



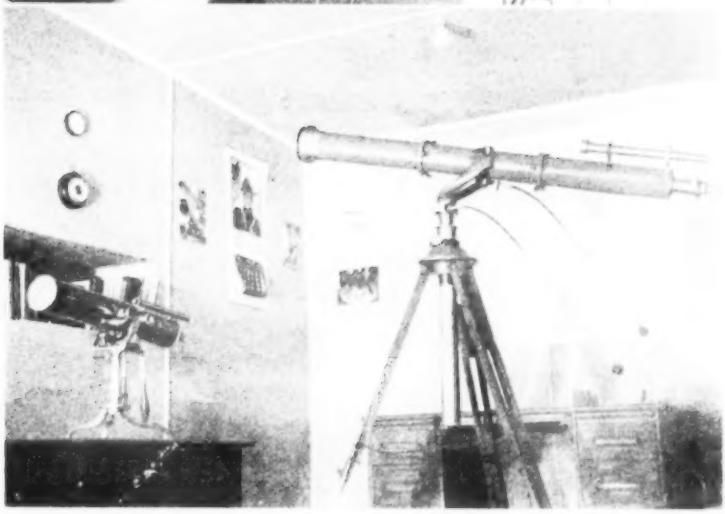
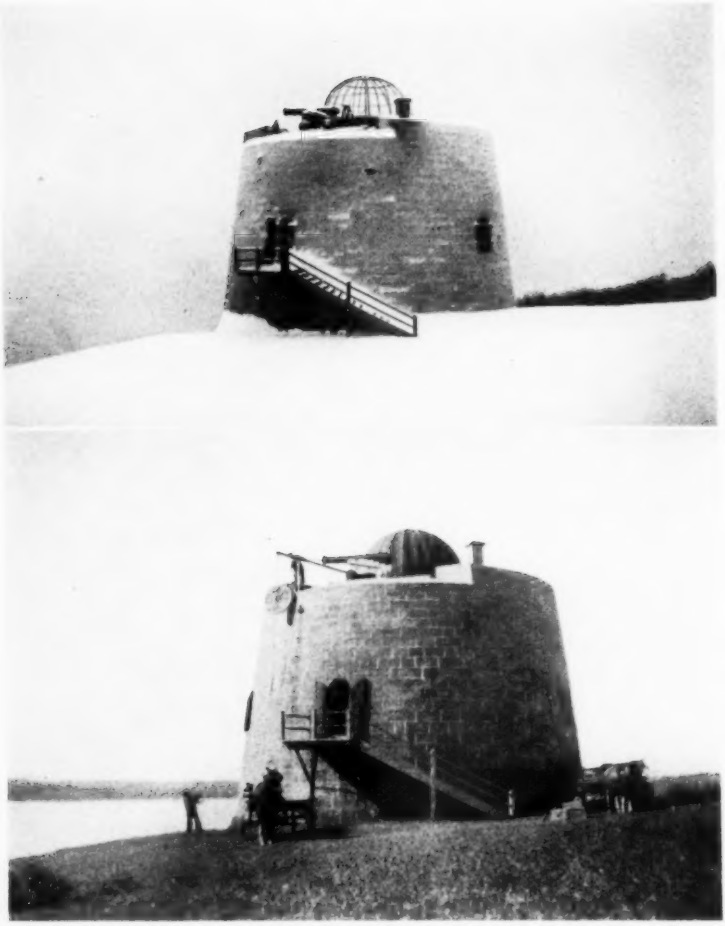


PLATE VII



QUEBEC CENTRE OF THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

Top: The Martello Tower with the matallic structure of the dome after the repairs of December 1942.

Bottom: The employees of Laval University hoisting parts of the mount of the Foucault Telescope.

Photographs by courtesy of the Service de ciné-photographie de la Province.

Journal of the Royal Astronomical Society of Canada, 1944.

THE JOURNAL

OF

THE ROYAL ASTRONOMICAL SOCIETY
OF CANADA

VOL. XXXVIII, No. 8 OCTOBER, 1944 WHOLE No. 337

THE QUEBEC CENTRE OF THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

A BRIEF SKETCH OF ITS ORIGIN AND GROWTH

By PAUL H. NADEAU

(With Plates VI, VII)

IN the history of the young science of astronomy in French Canada there is mention of many noted amateurs who lived in the city of Quebec during the past, but it is rather difficult to find any trace of their influence while they were living or of any existing work which they left to their successors. On the contrary, we recognize during the last fifty years a retrogression of astronomy in our Province, while in some other parts of the country we find this science has been very progressive. An evidence of this retrogression is the Quebec Observatory, the first established in Canada, in 1854. which was practically discontinued as an astronomical observatory in 1892 and was pulled down near 1935. There are many other facts of this nature, but it is of no use to report them here.

As a result everything was to be done when, some four years ago, a group of young amateurs decided to make an attempt to revive the interest in astronomy in our ancient city. Despite many difficulties encountered, their efforts were an evident success and it may be of interest to outline what was their procedure. They knew the errors of their predecessors, and the question was how to avoid them and make a choice of new methods of working. This account of the origin of the Quebec Centre of the Royal Astronomical Society of Canada will give an idea of these new methods.

First, it appeared necessary to make a union of all the energies

available, and with this object in mind the author of this article started publishing in a local newspaper articles on various astronomical subjects and on the desirability of forming a society of amateur astronomers. This was in May 1940. As these articles were published regularly each week, they did not fail to catch the attention of all persons interested, and a few months later it was possible to organize the society called, *Le Cercle astronomique de Québec*. The founding took place in a class room of Laval University on December 7, 1940, and its promoters were MM. Albéric Boivin, Jean Gagnon, Georges-Henri Montreuil and Paul-H. Nadeau.

The prime object of the founders was an observatory for housing the 4-inch refractor owned by one of them and for permitting an adequate use of it. Our idea was to erect it "somewhere" in the city, and we were fortunate indeed to obtain the most suitable place. This is one of the Martello Towers erected near 1830 as a part of the old fortifications of the Citadel. We find many advantages in this tower for the instalment of a temporary observatory: the platform on the top is wide enough and the horizon from there is not obstructed in any direction; it is central and easily reached from any part of the city and yet well isolated from the nearest buildings; finally, its position in the picturesque park of the Plains of Abraham, extending one mile along the promontory of Quebec, renders this site probably unique in the world for a city observatory.

The Park Commission graciously permitted us to occupy the tower for the purpose of the cultivation of astronomy and we made our first observations there on July 2, 1941. Thus, after a little more that half a year, the prime object of the society was attained. The rest of this account is almost entirely the story of the progress of this observatory.

For more than fifty years Laval University has been the owner of a 16-inch Foucault telescope built by Secrétan in Paris, in 1867. Its mirror is supposed to have been the work of Foucault himself. The authorities of the University kindly consented to lend the telescope to our organization and to contribute to its installation on our tower. A dome was necessary to shelter it conveniently and a group of members decided to undertake its construction themselves. It was agreed that a metallic frame covered with canvas was the best in the circumstances; the cost of all the materials needed was estimated at approximately $100.

It was not necessary to draw very elaborate plans: the time at our disposal, as well as our uncertain ability in mechanics, prevented us from worrying about details. As a matter of fact, the chief characteristic of the dome planned was ***simplicity,*** which means evidently easier execution and lower cost. For the circular base 16 feet in diameter, we chose angle-iron 1½ x 1½ x 3/16 in.; and for the 24 arcs, angle-iron 1 x 1 x ⅛ in., five of these to be doubled—the two on each side of the opening, the one diametrally opposed and the two others at 90°. The plans also provided for three sets of bracings: one to fasten the arcs to the base and the two others horizontally, at 1/3 and 2/3 of the height. For the rolling device used in revolving the dome, two sets of wheels were to be employed, one disposed with the axis horizontal, to support the effective weight of the dome, and the other with the axis vertical, to prevent horizontal displacements. This system permits the elimination of the complicated rolling track and it is quite as effective, as was realized after using. The shutter of the opening was also a very simple one: a rigid metallic frame curved to the same radius as the dome, to be moved by hand all round the dome by means of a spindle at the top.

Another characteristic of the dome was its liability to be taken to pieces in a short time. To attain this required nearly 500 extra borings and the use of approximately 300 bolts, but afterwards we came to the conclusion that it added to the simplicity and the easiness of the construction. The plans also indicate that the radius of the dome is only 8 feet long and the opening only 20 inches wide. These dimensions are much less than those to be expected to accommodate a tube 7 feet long, from the end to the declination axis, and a mirror 16 inches in diameter. But it is to be remembered that only one foot more in the radius of the dome would have considerably increased the cost of materials and the difficulties of construction. As to the width of the opening, it had to be of this minimum value because of the system adopted for the shutter, which requires to be as light as possible.

As it was designed, our dome with its surface of 400 square feet and its weight of more than 900 pounds, was expected to withstand the strongest winds without breaking, and so we confidently purchased the thirty angle-iron bars needed.

At that time, we had no idea of a place where we could undertake

our construction and find the tools needed. Furthermore, we were not quite sure that the finished dome, supposing that it would work well, would have the favour of the Park Commission. But we were confident in our good star and we resolutely engaged in the adventure.

Fortunately we learned that the stock of machines at the *Atelier Municipal* included a "Horsfeld Universal Iron Bender," exactly what we wanted for bending our angle-iron without heating. It was quite easy to obtain from the city authorities permission to use this machine during the night as well as some electric drills and mechanical saws. Thus the entire work could be performed in this machine shop.

The technique employed in curving our angle-iron consisted in giving to the bar on the machine a slightly more pronounced curve than the one desired (8 feet of radius) and rectifying it afterwards with the hammer. After we had ruined two or three bars, we were able to make a nearly perfect job in 15 to 20 minutes for each bar. This construction occupied our group of workers all the month of August 1941, and a part of September. Ordinarily, the working periods lasted from 7 o'clock to midnight and were repeated three times in a week on an average. But near the completion of the dome, when we had to assemble on our arrival the parts just completed, and to take them to pieces before retiring, an exercise that required three hours as a whole, it was necessary to pass well beyond midnight if we wanted to realize much progress. On two occasions we returned home at 5 o'clock in the morning.

Notwithstanding the many difficulties encountered, the dome was a fair success, and on December 26, 1941, it could be assembled on the tower and covered with its canvas shelter. During the summer of the next year (1942), the dome was elevated on an octagonal base consisting of wooden panels 5 by 8 feet, and finally the Foucault telescope was set under it, just before the lunar eclipse of August 25, 1942.

But an observatory is not complete without an office to store the books, charts, documents, etc., and also to accommodate the observers during the cold season. This construction was also made by our workers who changed into carpenters for the occasion. This office, where the Quebec Centre has established its headquarters, was found to be most useful and the money that it represents may be considered as a good investment. Actually, the objects belonging

to the society or consigned to its care are evaluated at $6,000. As the amount spent totalled less than $300, we realize the big contribution of the members in work and assistance of various kinds.

Our society counts a good number of "active" members, as can be seen by what has just been related. Some of them are anxious to do their share of the labour at any time and we see them whenever there is something to be done; some others prefer a speciality. This was the case of an important group of our founders, who were interested above all in the popularization of astronomy, a field of action which, in their opinion, ought not to be neglected by a society such as ours. So, we put into action our Committee of Vulgarization. This committee was responsible for five grand popular meetings which have been very successful. Three of them were held near our observatory in the city of Quebec, on September 29, 1941, on June 23, 1942 and August 25, 1942, respectively on the ooccasions of the approach of Mars, of the inauguration of the observatory and of the total lunar eclipse. Last year on June 11, 1943, the committee organized its first meeting outside the city, in Shawinigan Falls; and this year in Montmagny, on May 27 last. The programmes of these popular meetings consist generally in the presentation of the moving picture "The Universe as seen to-day through the largest Telescopes," with the collaboration of the *Service de Ciné-photographie de la Province*, and in exhibiting some curiosity of the sky through the telescopes brought with us. On every occasion, these meetings were favoured with exceptional weather conditions and were a complete success with respect both of assistance and organization. Another initiative of this committee was the opening of the observatory to the public during one hour every clear night all through the year. These visits were very popular from the beginning, but at last we had to cease the invitations, due to the large numbers of people. This direct contact with the public enabled us to know what the people in general were thinking of our observatory, information which is quite desirable in a democratic regime such as ours. This public opinion was very favourable, and to report the numerous congratulations and incitements to persevere in our work, expressed by persons of all conditions, English and French, young and old, would require many pages of this journal.

If we should make up a total of the hours devoted up to the present to the different fields of activity by our active members, we

should find that it is not vulgarization, writing of articles, or the construction of the observatory, that collects the maximum number, but our programme of practical observations. These observations have not been interrupted since the beginning of the observatory, despite the many other activities of our observers and the cold weather of the winter. They were the prime object of the observatory in the mind of the founders and they remain so. Every kind of observation possible with our present instruments has been tried, but we have made a choice of specialties such as northern light, sun spots and variable star observing. Interesting results have been obtained from our studies of the relation between sun activity and weather, and in the department of variables, in which we believe we lead the Canadian groups for the number of estimations per year. At this time, we have attained the mark of 3,000 estimations and we regularly watch over 150 variables. Our observatory is open to any amateur, member of the society or not, desirous to devote his leisure time to serious observations. Until now, considerable time has been spent by our senior observers in training such amateurs, and if the results are not yet very important, this is greatly due to the present conditions which affect particularly the youth. Nevertheless, our group of observers is progressing all the time in quantity and quality.

Now here are briefly outlined a few events which marked the beginning of our organization.

During his sojourn at the Citadel, in the beginning of the autumn of 1941, His Excellency the Governor General was visiting the different centres of activity in the city, mixing with the people and showing interest to what they were doing. Perhaps, the advertisements we were making through the radio and papers about our "Mars feast" organized in September 1941, had drawn the attention of some officers of his suite, but His Excellency the Count of Athlone really expressed the desire to visit our nascent observatory. Unfortunately, on the day fixed for the visit we had a heavy rain and we were deprived of this honour.

On December 2, 1942, a furious storm was the cause of damage to our observatory. Our dome, out of which some essential parts had been removed for repair, was blown off its base and carried a distance of over one hundred feet from the tower. It had to be reshaped and replaced during the cold month of December 1942.

September 1, 1943, is a memorable date in the history of astronomy in Quebec city: it marks the official recognition by the Government of the Province of the scientific and educational work of our society. This recognition was accompanied with the offer to appoint a permanent employee to take charge of the observatory, the first professional astronomer in the Province.

Other important events are those of the incorporation of our society into the Royal Astronomical Society of Canada, as the Quebec Centre, in March 1942, and its affiliation to the A.C.F.A.S. (the French Canadian Association for the Advancement of Sciences), in March 1944.

This present account shows evidently that in a few years of work our society has repaired many of the errors of the past. We have not yet restored the official observatory that existed fifty years ago, but we have an official astronomer and a prosperous society which entertains no intention to give up its work. The reader has noted the cause of its success and we may summarize what was done:

(1) First all persons interested in the advancement of astronomy in our city were invited to join a working group;

(2) This group did not make speeches about the necessity of an observatory to our city, but its members built it with their own hands; furthermore, what is more important, they have used it for practical work—our 3,000 estimations of variable stars are a good proof of it;

(3) By the organization of popular visits to the observatory and public "star parties," we permitted the public to let us know that it was interested in our work and that it was giving us its entire support. We had not to educate the citizens about astronomy: rapid developments of our organization, despite the bad conditions of the moment, prove this opinion very well.

These were our methods of work. It is quite clear that if they had been employed fifty or twenty-five year ago, they would have succeeded as well as to-day in our hands.

By way of conclusion may I pay a few tributes of sincere homage. First, to Camille Flammarion. If I have played any rôle in the story just outlined, it is due to his *Astronomie Populaire,* which I read some fifteen years ago. Secondly, to my numerous collaborators who shared with me the faith in our great work of science and progress.

Quebec, June 29, 1944.

REQUEST FOR AURORAL OBSERVATIONS

The following appeal for auroral observations has been received from Dr. C. W. Gartlein of Cornell University, Ithaca, New York. A description of forms of the aurora with instructions for their observation was printed in this JOURNAL, vol. 33, p. 46, .1939. It is hoped that many of our members, especially those away from city lights, will cooperate in this programme. Report forms may be secured from Dr. Gartlein.

The National Geographic Society and Cornell University have been studying the Aurora Borealis since 1938 and were given important aid by many amateur astronomers in the United States and Canada. The infrequency of auroras and war activities have reduced this observer group to a small number. Within the last year the observation of the aurora has become of some importance in the war effort and I have been urged to obtain the most complete observations possible for southern Canada and northern United States. I must have more observers since I cannot depend entirely on the automatic equipment now in operation at Ithaca.

I, therefore, appeal to you to see if some observational program can be started. It is most desirable that we have some observation during each dark hour (including the nights of no auroras) and this usually requires the close cooperation of a number of observers. For war purposes a description of the maximum phase is almost sufficient but it is very desirable to have the report give the sequence in which the various forms appeared, estimated brightness, maximum elevation above north, time of maximum and duration of the display. Simple sketches only of each stage are valuable and perhaps better than word descriptions, but the location of each fine detail is of no use. It will be necessary to send observations to us within about a week after they are taken. It is our intention to pay all postage expense but at present I know of no system for Canada other than reimbursing these groups at the end of a certain period.

If you can undertake this cooperation will you inform me as soon as possible, giving the times your people can observe and the number of instruction sheets and report forms you think you will need. It may be possible to supply a limited number of special glass filters to make the aurora more visible on moonlight nights.

Your cooperation would be a real help in the war effort. We trust that you will be able to offer the assistance we urgently need.

Sincerely yours,

C. W. GARTLEIN.

OCCULTATION: THEIR PREDICTION, OBSERVATION AND REDUCTION

By H. Boyd Brydon

(*Continued from page 294*)

The Trigonometric Bases of the Formulæ

In considering the trigonometric bases of the formulæ used in constructing the occultation diagram it is convenient to make use of the *YZ*-subsidiary plane. This plane intersects the fundamental plane of the diagram at right angles on the line of the *Y*-axis and contains the *Z*-axis from the star to the centre, *O*, of the earth. In Fig. 10 this plane lies in the plane of the paper. *YY* is the *Y*-axis; *ZO* the *Z*-axis. *O*, the centre of the earth, is the point where the three axes originate and is the *X*-axis seen end-on.

The Place-Ellipse. On the occultation diagram the place-ellipse is the projection of the observer's circle of latitude. All points on that circle are represented by corresponding points on the ellipse. The projection is an ellipse because the plane of the circle is tilted from the star by an angle equal to the declination of the star.

In Fig. 10 let *P* be a place on the meridian *PQSN*, lying in the *YZ* plane; *NS* the earth's axis and *EQ* the trace of the plane of the equator. Let *PL* be the diameter of the circle of latitude of the place *P* and *PC*, equal to *CL*, a radius. The angle *QOP* which the radius *OP* of the earth makes at the centre *O* of the earth with the plane of the equator is the latitude φ of the place and the angle *QOZ* is the declination δ' of the star.

Draw *PD* parallel to *NS*; *PB* parallel to the *Y*-axis, and *CB* parallel to the *Z*-axis, cutting the *Y*-axis in the point *H*.

1. *The Ordinate of the Centre.* The ordinate of the centre of the ellipse is its distance from *O*. In Fig. 10 the ordinate of the centre is *OH*. Since angles *NOQ* and *YOZ* are right angles, the angle *COH* is equal to the angle *QOZ*, the declination δ' of the star. Hence *OH* is equal to *CO* cos δ'. But as *CO* is equal to *R* sin φ where *R*, the radius of the earth, is taken as unity, the ordinate of the centre is sin φ cos δ'.

2. *Semi-major Axis.* The semi-major axis of the ellipse is *CP*,

the radius of the circle of latitude which is equal to OD or $R \cos \varphi$. That is, to the cosine of the latitude of the place.

3. *Semi-minor Axis.* In Fig. 10, PB is the semi-minor axis of the place-ellipse. Since angles NOQ and YOZ are right angles, angle PCB is equal to angle QOZ, the declination of the star. Now PB is equal to $CP \sin \delta'$. But as CP is equal to $\cos \varphi$ the semi-minor axis is equal to $\cos \varphi \sin \delta'$.

The declination of a star on the equator is zero. Since $\sin 0°$ is zero the semi-minor axis $\cos \varphi \sin \delta'$ is zero. That is, the place-ellipse for an equatorial star is represented on the occultation diagram by its major axis. It is a "line-ellipse."

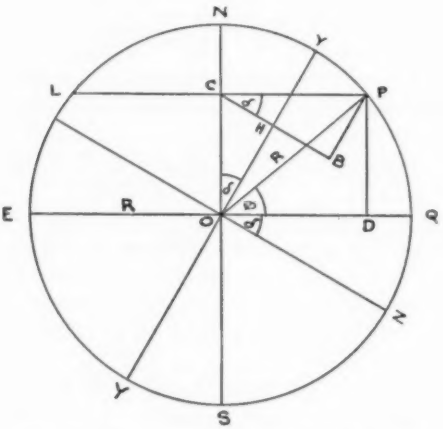


Fig. 10.—The axes and position of the ellipse of the place.

4. *Co-ordinates of Other Points on the Ellipse.* In Fig. 11, ZP is the trace of the YZ-plane. Let AMB be part of a circle of latitude φ; for example, that in Fig. 10. AB, the diameter at right angles to the meridian MP lying in the YZ plane, is the major axis of the ellipse which is the projection of this circle of latitude on the fundamental plane XY. Let PE and PT be meridians of any places E and P, having the same latitude φ. Angles such as t_1 and

t_2 are hour angles from the meridian PM, an angle of 15 degrees corresponding to one hour, since 360/24 equals 15.

Draw TC parallel to AB and TD parallel to PM. Then PD, equal to TC, is equal to $PT \sin t_1$. But PD is the distance of the point T from the YZ-plane, or as projected on the fundamental plane it is the abscissa of the point T from the Y-axis. Now PT is equal to $\cos \varphi$. Whence the abscissa of a point T on the latitude circle at an hour angle t from the meridian MP on the YZ-plane is equal to $\cos \varphi \sin t$; and, as the major axis of the ellipse of the place is equal to the diameter of the latitude circle, the abscissa of the corresponding point on the ellipse is also equal to $\cos \varphi \sin t$.

Similarly the ordinate from AB of any point T or E is equal to $\cos \varphi \cos t$; but, as the circle of latitude is tilted by an angle equal to the declination of the star, its projection on the fundamental plane is an ellipse whose minor axis is $\cos \varphi \sin \delta'$. Hence, the ordinate of the corresponding point on the ellipse is $\cos \varphi \cos t$ reduced in the ratio of the minor to the major axis, namely,

$$\frac{\cos \varphi \sin \delta'}{\cos \varphi} = \sin \delta'.$$

Whence the ordinate of the corresponding point on the ellipse is equal to the semi-minor axis $\cos \varphi \sin \delta'$ multiplied by $\cos t$ where t is the hour angle of the place.

5. *Position of the Ellipse on the Fundamental Plane.* In the occultation diagram the direction of the centre of the ellipse from the X-axis depends upon latitude, being northward in the northern hemisphere. The direction of the semi-minor axis from the centre of the ellipse depends upon the declination of the star.

In Fig. 10, the declination of the star being south or negative, the plane of the equator is seen from the star to be tilted upward or in the positive direction; the angle PCB is therefore positive and its sine is positive. Hence when the declination of the star is south or negative the semi-minor axis of the ellipse of a place in the northern hemisphere lies to the north of the centre of the ellipse. Conversely, when the declination of the star is north or positive the semi-minor axis of the ellipse lies to the south of the centre of the ellipse.

In Fig. 11 let the arrow indicate the eastward rotation of the

earth. Then the angle t_1 representing the time required for the place T to be carried by the rotation of the earth from the position T to the YZ-plane is, by definition, a negative hour angle and is plotted to the west of the Y-axis in the diagram. Similarly, angle t_2, representing the time elapsed since the place E was on the YZ-plane, is positive.

The Intercept Y. The value of the intercept of the moon's path and the Y-axis is given by the relation

$$Y = (\delta' - \delta)/\pi_m,$$

where δ' is the declination of the star; δ, that of the moon and π_m, the angle at the centre of the moon subtended by the earth's

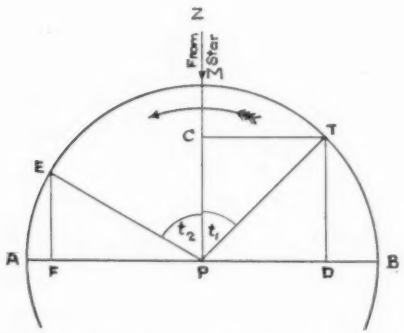


Fig. 11.—Co-ordinates of points on the place ellipse.

equatorial radius, is the moon's parallax. In circular measure π_m is computed from the relation

$$r/R = \pi_m/3438,$$

where

r is the earth's radius in miles or kilometers,
R is the moon's distance in the same units, and
3438 is the number of minutes of arc in one radian.[14]

In Fig. 12 the subsidiary YZ-plane is again that of the paper.

[14]Circular measure affords means of converting lengths into arc or angles. The unit is a radian. It is the length of the arc of a circle equal to the radius. Putting r equal to 1, since the circumference of a circle is equal to $2\pi r$, the length of a radian in degrees is 360/6.2832 equal to 57°.3 or 3437′.75 or 206264″.8.

YY', the Y-axis, is the trace of the fundamental plane, O is the centre of the earth and also the X-axis seen end-on. ZO is the Z-axis; EQ the trace of the equator, and M is the moon. Draw MO and with radius r, the equatorial radius of the earth, draw the circle E to represent the projection of the earth on the subsidiary plane. Then MO equals R, OE equals r, and $3438r/R$ equals the moon's parallax in the above equation.

The angle QOM is the declination δ of the moon; angle QOZ the declination of δ' of the star and angle ZOM is their difference $\delta' - \delta$. Draw MY parallel to ZO. Then angle OMY equals angle ZOM or $\delta' - \delta$, and since all rays of light from the star to the earth are parallel, Y is the point on the Y-axis where, as seen from

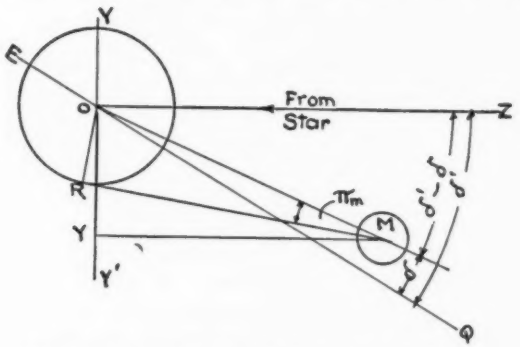


Fig. 12.—The value of γ, the intercept, as a function δ', δ and π_m.

the star, the moon is at the instant of conjunction. Now angle OMY/angle OMr is equal to OY/Or. But angle OMY is equal to $\delta' - \delta$; angle OMr is the moon's parallax and Or the radius of the earth, is unity whence

$$(\delta' - \delta)/\pi_m = OY/1,$$

or

$$Y = (\delta' - \delta)/\pi_m.$$

Semi-diurnal Arc. The formula for computing the semi-diurnal arc of a star,

$$\cos t = \pm \tan \varphi \tan \delta',$$

is derived from the spherical or "astronomical" triangle relating

the elevated pole, the observer's zenith and the star. In Fig. 13 let the circle *HZR* represent the meridian of an observer at *O* its centre; *P*, the (north) celestial pole; *OO*, the equator; *Z*, the observer's zenith; *HR*, the observer's true or astronomical horizon; *PO*, the 6-hour circle and *ZO*, the observer's prime vertical.

Also let S_1 and S_2 be stars on the horizon, S_1 having positive (north) declination and S_2 negative (south) declination. Then PS_1 is the hour circle of the northern star S_1 and ZS_1 its vertical circle. Similarly, PS_2 and ZS_2 are the hour and vertical circles of the southern star S_2.

In the spherical triangle *ABC* of which the sides *a*, *b* and *c* opposite the angles having the same identifying letters are arcs of great circles,[15]

$$\cos a = \cos b \cos c + \sin b \sin c \cos A,$$

whence by transposition

$$\cos A = \frac{\cos a - \cos b \cos c}{\sin b \sin c} \qquad \text{(a)}$$

In Fig. 13 this triangle is represented by PZS_1 or PZS_2 in which the side α_1 is the zenith distance of the star, 90° since the star is on the horizon; *b* is $90° - \varphi$, the complement[16] of the observer's (north) latitude; c_1 is $90° - \delta_1'$, the complement of the declination of the northern star S_2 or $180° - \delta'_2$, the supplement of the declination of the southern star S_2,[6] and cos *A* is cos *t*, the cosine of the semi-diurnal arc of the star expressed in arc instead of in time.

Since the cosine of an angle is equal to the sine of its complement or to minus the cosine of its supplement, equation (a) may be written

$$\cos t = \frac{\pm 0 - \sin \varphi \sin \delta'}{\cos \varphi \cos \delta'}. \qquad \text{(b)}$$

In equation (b) the sign of cos *t* is negative when latitude and declination have the same name and positive when they have opposite names. When cos *t* is negative the semi-diurnal arc of the star is the difference between 12 hours and *t*.

[15] *The Practical Essentials of Pretraining Navigation*, Skilling and Richardson; Henry Holt, publisher, N.Y. Contains a useful discussion of the fundamentals of spherical astronomy.

[16] The complement of an angle is its difference from 90°; the supplement is its difference from 180°.

When, to clear obstructions or to insure satisfactory seeing, the actual horizon is raised, for example 15 degrees, above the true horizon, the available semi-diurnal arc can be determined with sufficient accuracy for the present purpose by means of the following construction:

In Fig. 13 let the circle *HZR* represent both the plane of the horizon and, by rotating it through 90° on the line *HR*, also as required the observer's meridian. As the horizon, divide it into hourly or smaller intervals and as the meridian into degrees of

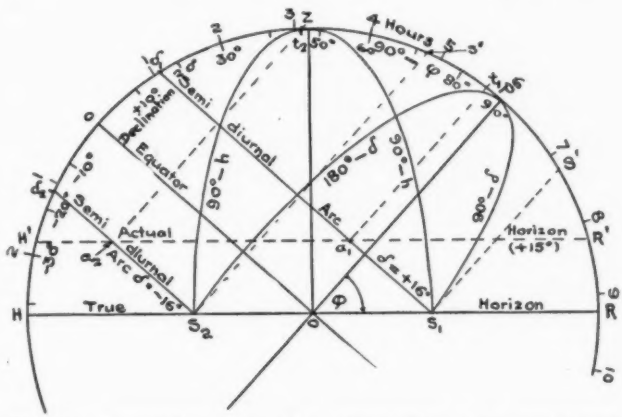


Fig. 13.—Computation and graphic determination of the semi-diurnal arc of a star.

declination as shown, beginning at the equator in both cases. Considering the circle as a meridian, lay off the arc RR', the angle of elevation of the actual above the true horizon and draw $H'R'$ parallel to HR to represent the actual horizon. From the equator lay off δ'_1 and δ'_2 the declinations of any stars S_1 and S_2 and draw $S_1\delta_1'$ and $S_2\delta_2'$ parallel to the equator, cutting the actual horizon $H'R'$ in a_1 and a_2.

Through S_1 and S_2 draw S_1S' and S_2S'' perpendicular to the equator, meeting the circle HZR (now again taken as the plane of the horizon) in S' and S''. Then the times indicated by the points S' and S'' are respectively the true semi-diurnal arcs of the stars

S_1 and S_2. Next, through the points a_1 and a_2 on the actual horizon draw a_1t_1 and a_2t_2 perpendicular to the equator, meeting the circle *HZR* in t_1 and t_2. Then the times indicated by the points t_1 and t_2 are the observable semi-diurnal arcs of the stars S_1 and S_2, respectively.

Altitude of the Star and Position of the Moon's Vertex. There seems to be a contradiction between the position of the moon's vertex *T* as it appears in an occultation diagram and in the sky. Instead of being at the top of the diagram, the vertex leans away therefrom by the amount of the parallactic angle *q*; is indeed where one would expect the north point to be. There is no contradiction, however, only a difference of point-of-view. The moon is observed from a point on the earth's surface while the diagram depicts appearances at the earth as seen from the star. But while that statement is correct it does not remove the difficulty. Again, it is by no means evident why the foreshortened length of the projection of a radius of the earth, for example the line *OD* (Fig. 14A) on the fundamental plane should be a measure of the moon's altitude as observed from the end of that radius. These points are now discussed.

Altitude of the Star. In an occultation diagram such as Fig. 14A, the line *OD*, from the centre of the earth to the position of the observer, can be considered as the trace of an arc of a great circle whose plane intersects the fundamental plane at right angles and at the parallactic angle *q* from the *Y*-axis. The observer at *D* is on this arc which contains the *Z*-axis.

Looked at as the arrows fly in this figure, this arc will appear as in Fig. 14B, where *FPE* is the arc and *O* is its centre. The diameter *FOF'* is the trace of the fundamental plane and *ZO* is the *Z*-axis. The star is thus in the zenith of the point *Z*. Take *OC* equal to *OD* of Fig. 14A and draw *CS* parallel to *ZO*. Then the point *P* where *CS* cuts the circumference of the circle is the position of the observer and the arc *ZP* or angle *ZOP* is his distance from the point *Z*; that is, the arc *ZP* or angle *ZOP* is the zenith distance of the star from the observer. Draw *OP*, a radius of the earth to the position *P* and *HPR* at right angles to it and tangent to the circle at *P*. Then *HPR* is the trace of the observer's horizon plane and angle *RPS* is the altitude *h* of the star.

Since *CS* is parallel to *ZO* and *HR* perpendicular to *OP*, angle *COP* is equal to angle *RPS*. But *OC* is the cosine of the angle *COP*, whence the line *OD* in the occultation diagram Fig. 14A is the cosine of the altitude of the star.

The Vertex of the Moon's Disc. In Fig. 14B, *M* is the moon at the moment of occulting the star. *T* and *B* are the positions

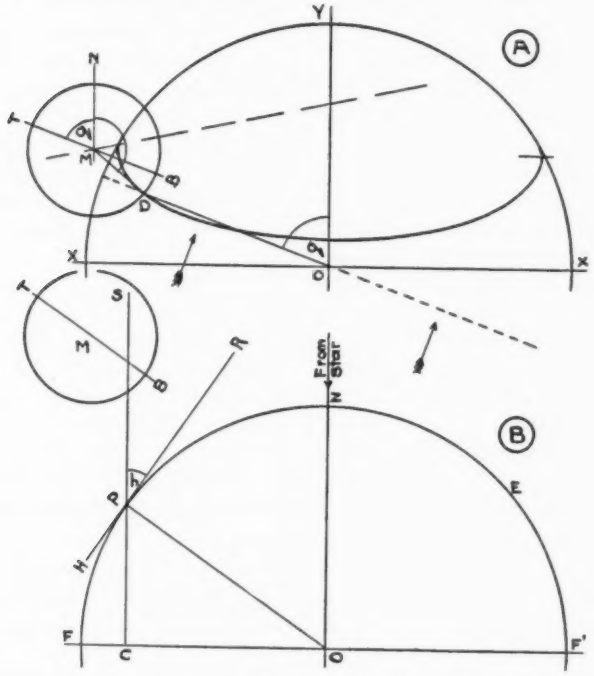


Fig. 14.—Relation between the altitude of the star and the parallactic angle.

of the same named points in Fig. 14A when transferred to the plane of the great circle *FPE*. As the point *T* is the farthest point of the moon's disc from the observer's horizon plane *HPR* it is the top point of the moon's disc or the vertex.

Returning to Fig. 14A, since *TB* is parallel to *DO* and *NM* to *YO*, the angle *TMB* is equal to angle *NMB* plus the parallactic angle.

Observation

In the prediction of occultations approximation is unavoidable. In observation accuracy is essential. For the observation of an occultation to be of service two facts must be known, (1) the observer's position and (2) the time. Position can be checked and re-checked. An error in recorded time cannot be rectified.

For prediction it suffices that the geographic position be known to within a mile or two. For an observation to be worth reducing the observer's latitude and longitude must be known to within 100 yards and his altitude above mean sea level to within 500 feet in order that his geocentric latitude and his hour angle from Greenwich may be computed correctly.

This accuracy can be obtained easily from a large scale, one inch to the mile or larger, government map; altitude above mean sea level by reference to the nearest bench mark.

Mean sea level is the datum for all precise levelling. It corresponds closely to the theoretical ellipsoid of revolution represented by Hayford's spheroid of 1909, in which the accepted equatorial radius of the earth at mean sea level is 6378.388 km., or 3963.35 miles, and the compression 1/297.0. From these data the radius at other latitudes is easily computed by the aid of tables found in the nautical almanacs.

Consultation with a government land surveyor or a city or a railroad civil engineer, who will be glad to assist when the reasons for close accuracy are stated, will be of great help in fixing geographic position.

Prof. Brown's statement (*loc. cit.*) that in timing an occultation an accuracy of one second is sufficient assumes that the observer's position is accurately known. It in no way relieves him from the duty of using the greatest possible care in timing. In the reduction of an occultation the primary result is a quantity which at most does not exceed two or three seconds of arc. A second of arc being but one-fifteenth of a second of time the need for accuracy is clear.

Errors in timing arise from two sources: (1) lack of knowledge

of the error and rate of the timepiece used for reference, here called the "standard timepiece"; (2) incorrect reading or recording the time of the occurrence. The first is discussed later. Errors of the second class can be prevented in two ways: the first is simply a matter of having one's wits about one when reading and recording the time. Perhaps the most common error of this sort is a mistake of a whole second or minute; the second is the reversal of figures when recording the time.

When an assistant is not available, a stop-watch will be found most useful as it enables the readings to be checked by making double comparisons with the standard, the first with the stop-watch running, the second after it has been stopped. The seconds hand of the stop-watch is started on the instant when the star is seen to vanish or reappear. The watch is then carried without shaking or jarring to the standard timepiece and its reading noted and recorded when the seconds hand of the standard reaches a definite second or minute, and is then stopped when the second comparison, perhaps half a minute later, is made. All readings are entered without delay in the rough log and the correct time of the occurrence determined later after applying the necessary corrections from the rating logs of both timepieces.

Stop-watches are subject to two important defects: a jump of a fraction of a second, perhaps one or two fifths when started, and a change of rate when the seconds hand is running. The first is checked by close observation, the second by comparison with the seconds hand of the standard, stop-watch seconds hand stopped and running.

Preferably the standard timepiece should be a weight-driven clock controlled by a seconds pendulum. An electric clock driven by current from the supply mains is useless for this purpose. Its speed depends wholly on the speed of the generators in the power station and will vary as the load on the station changes. Lacking a pendulum clock or a ship's chronometer, a good watch can be used, but whether clock or watch, it must have a clearly legible seconds hand, preferably of the centre seconds type. The pinion of the seconds hand should be concentric with the graduated circle of the seconds dial and when once set the seconds hand should remain in step with the minute hand. This is not always the case.

The merit of a clock or watch depends less upon its keeping accurate time than on running at a constant rate. As neither quality is obtainable the correction and rate should be determined as frequently as possible by government time signals and recorded in a special log. Failing this, it is essential that the correction be ascertained and recorded as soon as possible before and after the observation so that the proper correction for the instant of the observation can be interpolated from these two determinations.

To quote W. W. Campbell (*Practical Astronomy*, p. 83): "The chronometer correction is the amount which must be added to the reading of the chronometer to obtain the correct time. It is positive when the chronometer is slow. The chronometer rate is the daily increase in the chronometer correction. It is positive when the chronometer is losing."

When the correction and rate of the standard timepiece are known, it is not difficult to determine the time of an occurrence to one-fifth of a second.

One caution bears repetition. Only time signals sent out from a government radio time signal station are suitable for determining the clock correction. Radio announcements that it is exactly such a time by somebody's watch are worse than useless. Details of government time signals can be obtained by application to the office of the government time service.

Care of the Standard Timepiece. The standard timepiece should not be exposed to drafts, nor to the sun. It should be near but not against an inside rather than an outside wall and be enclosed in a dust-proof case. The surrounding air temperature should be as even as possible. The amount of the correction is immaterial but it is important that variations in the rate of going should be small. Arrangements for adjusting the rate by adding or removing weights from the pendulum are of doubtful value in the case of an ordinary clock. Inevitably the rate will change as temperature and barometric pressure change; increase in either causing the clock to run slower, hence the need for checking frequently, daily if possible, the correction and rate. Beyond winding at regular intervals the clock is best left undisturbed.

To prevent vibration, when a spring-driven clock is used it should be supported on sponge rubber pads; if a watch, on a hook

covered with rubber tubing. When being wound, a clock or watch should not be shaken nor twisted. It should be fully wound at the same time each day so that the same part of the spring is always used. Once set, the regulating lever engaging the hair spring should not be moved. On no account should the hands be turned backward unless a releasing device is fitted; even then it is undesirable.

Counting. Whether or not the ticks of a clock can be heard when at the telescope, the observer should practice counting seconds; starting with "nought"[17] and continuing until he sees the seconds hand of the standard clock reach a definite second or minute as when a stop-watch is used. The count may stop on a fraction of a second. Accuracy in counting comes with frequent practice to get "the feel" of counting seconds but an accuracy of one or certainly of two seconds in sixty is not difficult to achieve.

If the watch can be placed in charge of an assistant who can count seconds accurately, he should begin the count aloud when warned that the occultation is imminent, starting with nought at beginning of a minute which he should note down. When the star vanishes or reappears the observer calls and both he and the timekeeper independently note and write down his own estimate of the seconds and fraction and then the minutes and hour of the call. When the timekeeper alone notes the time the objection is made that too many separate mental and muscular reactions are required between the occurrence and noting the time.[18]

Personal Equation. By personal equation is meant the error, usually a fraction of a second, made by an individual when observing the time of an occurrence. Some persons habitually estimate earlier, others later than the actual instant. The personal equation of a given observer generally remains of the same kind, early or late, but varies with experience, state of health and age. It varies slightly with the magnitude of the star, being greater as

[17]Because one commonly counts things instead of intervals of time, the habit of starting a count with "one" is difficult to overcome. Steady practice is needed.

[18]See an important paper by Dr. R. K. Young; *Occultations of Stars*; this JOURNAL, vol. 24, p. 211, 1930.

the star is fainter, and to some extent with the aperture and magnification used. It varies also with the phase observed, being as might be expected, least with disappearances at the dark limb, greatest with reappearances at the bright limb. The method of observation, eye and ear, chronograph or stop-watch, affects the personal equation. Russell, Dugan and Stewart say: "This personal equation (though usually less than $0^s.1$ for chronographic observations) is an extremely troublesome error." (*Astronomy*, p. 63.) Dr. Otto Klotz, on the other hand (this JOURNAL, vol. 13, p. 232, 1919) considers the eye and ear method as accurate as the chronographic; but Phillips [20] presents the following Table as summarizing the findings of a number of investigators:

Method	*No.*	*Av. P.E.*	*Variation*	*Range*
Chronograph.....	13	$-0^s.31$	abt. $\mp 0^s.03$	$-0^s.10$ to $-0^s.46$
Eye and Ear.....	4	$-0\ .03$	abt. $\mp 0\ .06$	$+0.\ 09$ to $-0\ .16$
Stop-watch.....	2	$-0\ .06$	abt. $\mp 0\ .10$	$-0.\ 04$ to $-0\ .07$

He remarks: "Whilst the chronograph gives the largest personal error or lag," it also gives the steadiest lag, whilst the eye and ear method gives the smallest lag but the greatest variability from the average in the individual observations. The stop-watch observations hold a middle position in both respects" (vol. 36, p. 407).

The above figures are the results of experiments in the laboratory with machines designed to present artificial occultations and are smaller than those met with in practice. Thus Campbell, *loc. cit*, p. 63, notes: "the relative personal equation of two most skilful observers, Bessel and Struve, was zero in 1814; $0^s.8$ in 1821; and $1^s.0$ in 1823."

Seeing and Magnification. When observing with the unaided eye or field glasses, neutral-tinted glasses will be found useful in reducing glare. In the telescope the dazzling brightness and irradiation of the moon and bright stars can be reduced by using a solar (Herschel) diagonal eyepiece, high magnification or by keeping all but the important limb of the moon out of the field, bringing it to the centre just before the disappearance occurs. The last is not very satisfactory unless the telescope has an excellent

[20] *Personal Equation in observing Occultations, Pop. Ast.*, vol. 35, p. 491, 1927; vol. 36, p. 403, 1928. These papers include a good bibliography on the subject.

driving clock. It is difficult to maintain the moon in the desired position, which distracts the attention from the object of the observation. High magnification does not affect the brightness of a star but darkens the rest of the field, including the moon's disc. For this reason it is most valuable in the case of faint stars. An objection to high magnification is that with bright stars and good seeing the star may be surrounded with one or more diffraction rings, while with poor seeing, jumping of the star and boiling of the moon's limb are greatly increased. Experience and the trial of various powers at the time are the best guides.[21]

Irregular Refraction. There are well authenticated cases reported by Webb and others of the star appearing to enter upon the disc of the moon. The phenomenon is noted here that the observer, being freed from surprise should it happen, may be able to apply his mind to observing and noting the details of the occurrence until they can be entered in the log.

Regarding it, Sir J. Herschel has said: "There is an optical illusion of a very strange and unaccountable nature which has often been remarked in occultations. The star appears to advance actually *upon* and *within* the edge of the disc before it disappears, and that sometimes to a considerable depth. I myself have never witnessed this singular effect but it rests upon the most unequivocal authority." The cause more probably may be irregular refraction, similar to that which causes a star to jump, than merely an optical illusion in the sense of an occurrence imagined by the eye. Campbell remarked, *loc. cit.*, p. 33 note, "It is known that appreciable deviations in azimuth are sometimes produced by refraction, especially in observations made very near the horizon; but as they are due to abnormal and unknown arrangements of the strata of the air there is unfortunately no direct method of eliminating them."

If the phenomenon is observed, a careful, detailed description of all the circumstances should be written up in the log of the observation and published. Such data may serve to throw light on these "abnormal and unknown arrangements" of the air strata

[21]In this connection see the chapter on Seeing and Magnification in Dr. Louis Bell's *The Telescope*.

and may have a not unimportant bearing on other matters than the timing of occultations.[22]

Whatever may be the cause, the practice is to accept the final disappearance of the star as the time of the phase.

[22]A discussion of the theory of horizontal refraction given by Andoyer, *Cours d'Astronomie*, Edition II, Chap. VII, p. 162, indicates that for a zenith distance of 90° the horizontal refraction will amount to about 2200.

(*To be continued*)

ABSORPTION LINE INTENSITIES AND SPECTRAL TYPES FOR THE O STARS

By R. M. Petrie*

Introduction

THIS communication presents the results of measurements of the intensities of the principal absorption lines, found in the usual photographic region, in the spectra of the hottest stars of the ordinary stellar sequence, that is, the O-type stars. The primary purpose is to examine the behaviour of the stronger absorption lines, as the temperature varies, in order to derive criteria for assigning stars to their proper places in the O-type sequence. The strong absorption lines selected for measurement are essentially those produced by hydrogen, neutral and ionized helium, and triply-ionized silicon.

Two extensive lists of *measured* line intensities in the helium stars have been published by Williams[1] and by Rudnick[2] and several lists of selected lines have appeared.[3] The studies of Williams and Rudnick have placed our knowledge of line intensities upon a firm basis as far as the B stars are concerned, but the O stars are rather inadequately represented. While there are, in the two lists, sixteen different O-type stars there is but one example of O6, three of O7, and the remainder are of later subdivisions. It was evident that line intensities were needed for the "earlier" part of the O class and the measurements in this paper were undertaken to supply the required data. Of the nineteen stars for which measured line intensities are given (Table 1), eight are found to be "earlier" than O7 while twelve stars are added to the sixteen referred to above. Line intensities are now available, therefore,

*On leave of absence from the Dominion Astrophysical Observatory on war work.

[1] *Ap. J.*, vol. 83, p. 279, 1936.

[2] *Ap. J.*, vol. 83, p. 439, 1936.

[3] See, for example: C. T. Elvey, *Ap. J.*, vol. 70, p. 141, 1929; and vol. 71, p. 191, 1930; Miss E. T. R. Williams, *Harv. Circ.*, No. 348, 1929; and S. Gunther, *Zeit. f. Astrophysik*, vol. 7, p. 106, 1933.

for twenty-eight stars distributed as follows:

O5 .....3 stars	O8 .....4 stars
O6 .....3 "	O8.5.....3 "
O6.5.....2 "	O9 to B1....5 "
O7 .....8 "	

The line intensities are discussed and tabulated for individual stars in the following section. The rest of the paper is concerned with the problem of securing criteria which will arrange the stars in an unambiguous order with respect to their temperatures, that is, of providing criteria for spectral classification. At the same time the line intensities are examined in order to determine whether they are sensitive to luminosity effects of the sort existing in the spectra of the B stars.[4]

The Line Intensities

The total absorptions of the spectral lines were derived employing usual spectrophotometric methods. The spectrograms were obtained with the single-prism spectrograph yielding a linear dispersion, at Hγ, of 30 A/mm. The plates were calibrated at various wave-lengths in a calibrating spectrograph in which the intensity variation was produced either by a neutral tint wedge or a rapidly rotating step-sector. Stellar and calibration spectra were analysed by the self-recording photoelectric microphotometer and the record produced by it was transformed to one giving intensities on a natural scale by an instrument designed and described by Beals.[5] The final record represents a magnification of the original spectrum of 200-fold (in some cases 80-fold) in the dispersion coordinate while the intensity coordinate has a maximum scale of 25.4 cms. On such a record line intensities are quickly and accurately obtained from the area of the line with the aid of a planimeter.

The intensities of the spectral lines are given in Table 1, the unit in all cases being one angstrom of complete absorption. The stars are listed according to *The Henry Draper Catalogue* number, and the B.D. number or the familiar constellation names are given for the brighter objects. Then follow columns giving the spectral

[4] E. G. Williams, *P.A.S.P.*, vol. 46, p. 292, 1934.

[5] This Journal, vol. 38, p. 65, 1944.

types, the number of plates measured, and finally the individual line intensities. Under the heading "Spectrum" are given, first, the spectral types assigned by Pearce from visual estimates,[6] and, secondly, the spectral types as determined from measured line intensities and described in the following section.

TABLE 1. MEASURED LINE INTENSITIES IN O-TYPE STARS

H.D.	Name	Spectrum		Plates	Hydrogen	
		Vict. Rev.	Meas'd		δ	γ
14947	+58° 467	05fk	05.0	2	1.04	1.49
17505	+59° 552	07k	07.0	2	2.95	2.52
24912	ξ Persei	07nk	07.0	1	2.26	2.33
36816	λ' Orionis (A)	08sk	08.0	2	2.54	2.56
37043	ι Orionis	08sk	08.0	2	1.60	2.24
41161	+48° 1339	09nk	07.0	2	2.67	2.34
46150	+ 5° 1283	06k	06.0	2	2.45	2.48
47129	+ 6° 1309	08ek	07.0	6	1.18	1.65
54662	−10° 1892	07k	06.5	1	2.21	2.68
188001	9 Sagittae	07fk	07.0	1	1.69	1.77
190429N	+35° 3930	05nfk	05.0	2	1.44	1.46
190864	+35° 3949	06fk	06.0	2	1.64	1.82
191201	+35° 3970	B0k	B0	2	2.48	2.82
192281	+39° 4082	05n	05.0	1	2.23	2.15
192639	+36° 3958	07sfk	07.0	2	1.48	1.76
202214	+59° 2334	09sk	08.5	2	3.41	3.54
210839	λ Cephei	06nek	06.0	2	1.76	2.04
214680	10 Lacertae	09sk	08.0	2	3.31	3.64
224151	Boss 6142	B0k	B1.0	2	1.96	2.45

There are, in all, six stars in common with Williams' list. A comparison of measures on lines stronger than 0.5 equivalent angstroms indicates that the intensities determined by the writer are about ten per cent greater than those published by Williams. It is, perhaps, doubtful whether this is a real systematic difference in view of the limited material but further evidence will become available from a study of the B stars, now begun.

[6]These are referred to as the Victoria Revised Types, and are published in *Pub. Dom. Astro. Obsy.*, vol. 5, No. 2, 1931.

The behaviour of the spectral lines in O stars is shown in Figure 1 where, for each element, the mean intensity is plotted against measured spectral type. The values in Table 1 have been supplemented by the intensities given by Williams and by Rudnick. The plots tell, at a glance, how the lines vary in intensity and only

TABLE I. MEASURED LINE INTENSITIES IN O-TYPE STARS (*Cont'd*)

	Helium I					Helium II			
H.D.	4009	4144	4388	4026	4471	4200	4542	Si IV 4089	Mg II 4481
14947				0.74	0.41	0.73	0.74		
17505		0.28	0.26	0.68	0.66	0.61	0.60	0.18	0.10
24912		0.36	0.48	0.91	0.98	0.91		0.37	0.07
36861	0.08	0.14	0.23	0.96	1.03	0.48		0.52	0.17
37043		0.30	0.49	0.70	0.90			0.30	0.12
41161	0.32	0.34	0.56	1.12	1.08	0.74	1.05	0.41	1.12
46150		0.14	0.28	0.62	0.39	0.70	0.84	0.07	0.12
47129		0.26	0.34	0.86	1.03		0.74	0.39	
54662	0.21	0.20	0.31	1.00	0.72	0.68	1.13	0.26	0.18
188001	0.17	0.50	0.56	0.92	1.30	0.77	0.70	0.61	0.28
190429 N	0.17	0.20	0.30	0.66	0.38	0.66	1.42		0.16
190864	0.07	0.14	0.22	0.68	0.58	0.72	0.91	0.16	0.11
191201	0.38	0.55	0.73	0.90	1.17	0.22		0.40	0.09
192281			0.17	0.84	0.34	1.05	1.22	0.18	
192639	0.12	0.20	0.20	1.10	1.16	0.60	0.90	0.36	0.10
202214	0.49	0.64	0.52	1.04	1.22	0.40	0.45	0.41	0.35
210839			0.18	0.62	0.81	0.78		0.20	0.16
214680	0.26	0.54	0.65	1.65	1.38	0.66	0.68	0.72	0.30
224151	0.43	0.44	0.72	0.72	1.00			0.49	

brief comment is necessary. The values of neutral and ionized helium and those for triply-ionized silicon show a well-defined correlation with spectrum to be expected from similar plots for the B stars[7] and from the principles of ionization and excitation applied to the assumption that stellar temperatures increase steadily from O9 to O5. The diagram for ionized magnesium (λ4481) shows considerable scatter a good deal of which must be attributed to accidental error, since the line is always weak. In

[7] *e.g.* E. G. Williams; *Ap. J.*, vol. 83, p. 303, 1936.

addition, this line exhibits a definite luminosity effect in the B stars and may be similarly affected here. The diagram for hydrogen (mean of Hγ and Hδ) shows a scatter considerably greater than that attributable to accidental error of measurement. From a correlation with luminosity, to be described later, it does not appear that the large range in the hydrogen line intensities, at one spectral

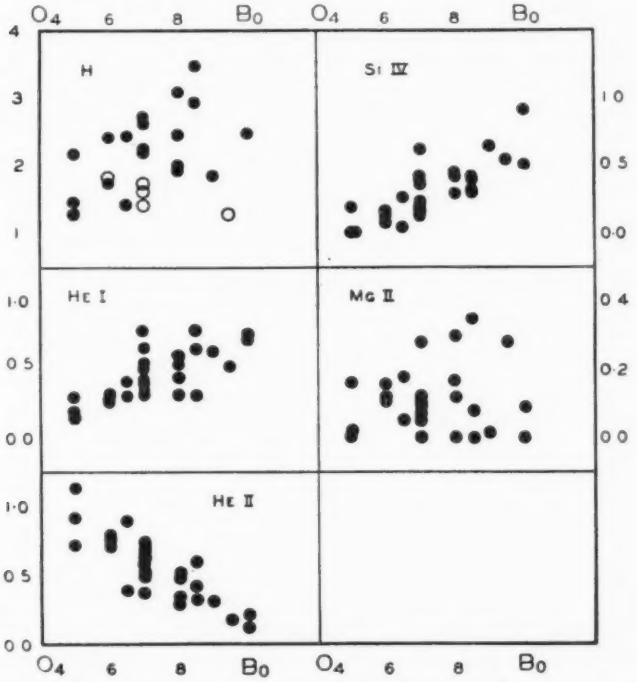


Fig. 1—Line Intensities plotted against Spectral Type.

subdivision, is due to an absolute-magnitude effect and it is believed that the tendency for hydrogen to appear in emission is largely the cause of the scatter. To illustrate the effect those stars in which Hα is definitely bright are represented on the diagram by open circles; it is plain that these objects contribute largely to

the vertical scatter. It must be remembered also that lines of ionized helium, of the same series as those defining the variation of that element in Figure 1 are blended with the hydrogen lines and thus modify their natural variation. For example, at O5 the features Hγ and Hδ must be nearly fifty per cent due to ionized helium, while at O8 the hydrogen contributes about eighty per cent to the combined spectral feature.

One further interesting point is brought out by the measures, namely, the ratio in intensity for the singlets and triplets of the diffuse series in helium. This ratio is of importance in the B stars since it has been found to vary with excitation, but to be largely

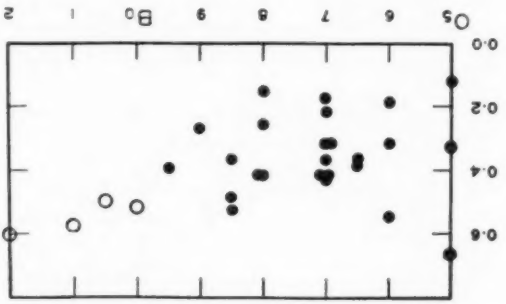


Fig. 2.—The singlet-triplet ratio in the diffuse series of helium.

independent of luminosity, and is thus of the greatest value as a criterion of spectral type. The singlet-triplet ratio (defined as the mean intensity of 4388 and 4144 divided by 4471) for the O stars is shown in Figure 2 with mean values for the early B stars marked by open circles. It is apparent that no real variation is found to extend into the O stars and so this criterion must be restricted to spectra later than O9. A satisfactory explanation for the variation of the singlet-triplet ratio in B stars was given by Goldberg[8] who showed it was a consequence of the relative positions of the singlets and triplets on the curve of growth for the diffuse series. An

[8] *Ap. J.*, vol. 89, p. 623, 1939.

extension of Goldberg's argument to temperatures at which the helium lines are fading out predicts the constancy of the singlet-triplet ratio in the O stars. If this explanation is correct we would expect a similar constancy to obtain in the later B-type spectra.

Spectral Classification

The principle of the modern "revised" spectral classification of the O stars was placed upon a firm basis by H. H. Plaskett[9] who showed that the ratios of certain absorption lines defined, unambiguously, the sequence O5...O9 as a function of excitation in the stellar atmospheres. His proposed line ratios, and the more recent Victoria Revised Classification as well as others, rest upon visual estimations of line strengths. In 1936 Williams published an important paper[7] dealing with the classification of the B stars and gave criteria, from measured line intensities, suitable for "late" O-types. Many of the lines employed by Williams are, however, of low intensity and subject to large accidental error of measurement upon low-dispersion spectra and some of his criteria are not suitable for spectral types earlier than O7.

In examining the measured line intensities to be used throughout the range O5 to O9 certain precepts have been followed applicable to all the helium stars, since this investigation is but part of a more extensive one which envisages the measurement of selected lines in the spectra of all the B stars observed at Victoria. Since the aim of this work is to assign spectral types and luminosities only one or two spectra of each star can be analysed and, furthermore, most of the spectra are obtained with relatively low dispersion, *i.e.* single prism with linear dispersions at Hγ ranging from 30 to 90 A/mm. In order to derive reliable line intensities and to preserve homogeneity and continuity throughout the program it is obvious that only the more prominent spectral features can be considered. A wide range of spectral type can be covered in this way and spectra of different linear dispersions can be referred to the same system. Therefore the lines measured in the O stars are the strongest features in the spectral region $\lambda\lambda$4000-4500 A.

[9] *Pub. Dom. Astro. Obsy.*, vol. 1, p. 325, 1922.

The line intensities presented in the preceding section amplified by the addition of the measures of Williams and Rudnick have been studied from the standpoint of selecting criteria for the determination of spectral type. Only ratios of line intensities were considered in order to minimize possible luminosity effects

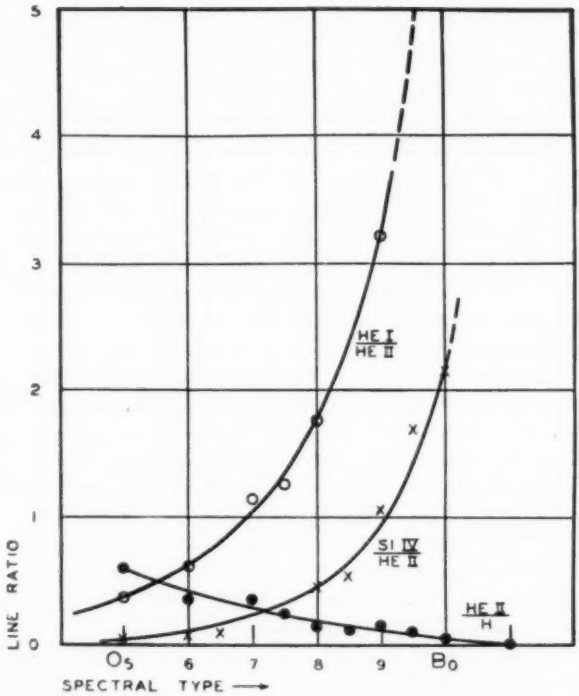


Fig. 3.—Line ratios defining Spectral Type in the O-stars.

and individual abnormalities. Three ratios follow the principles generally accepted in classifying the O stars from their absorption lines and utilize all the strong lines which can be measured readily in the ordinary region. The ratio HeI/HeII, which is the most sensitive of the three, is constructed by summing the intensities

of λλ4144, 4388 and 4471 and dividing by the sum of λλ4200 and 4542. The ratio HeII/H is formed from the sums of λλ4200 and 4542, and λλ4101 and 4340, while that designated SiIV/HeII is found by dividing the intensity of λ4089 by the sum of λλ4200 and 4542. The mean values of these three ratios are given in Table 3.

Using the criteria just described, spectral types were assigned to the stars for which measures were available and these measured types are given in Table 1, column four, for those stars studied by the writer. The additional stars for which line intensities were published elsewhere have also been classified and the assigned types are given in the following table. (Table 2.)

TABLE 2. SPECTRAL TYPES FOR STARS NOT MEASURED AT VICTORIA

H.D.	B.D. Number Name	Spectrum		
		Vict. Rev.	Measured	
30614	α Camelopardalis	09sek	09.5e	
37022	θ'Orionis (C)	07k	06.5	
47839	S Monocerotis	07sk	07.0	
57060	29 Canis Majoris	09sfk	07.0	
57061	τ Canis Majoris	09sk	08.5	
167971	−12° 4980	—	08.0	Classed as 08.0 by Williams
193322	+40° 4103	08k	08.5	
195592	+43° 3630	B0sk	B0	
210809	+51° 3281	08k	09.0	

TABLE 3. CLASSIFICATION RATIOS FOR O STARS

Type	HeI/HeII	HeII/H	SiIV/HeII
05	0.4	0.6	0.0
06	0.6	0.4	0.1
07	1.0	0.3	0.2
08	1.7	0.2	0.4
09	3.4	0.1	0.9

The classifications given here are essentially on the system proposed by H. H. Plaskett[9] and adopted by the International

Astronomical Union,[10] as set forth in a concise and valuable discussion by Curtiss,[11] and are based upon the types assigned by Pearce[6] and Williams[7] in setting up the classification criteria. The correlation between Pearce's types and those assigned in this paper is shown in Figure 4 which also indicates the comparison with Williams' measured types. It will be seen that the agreement among the lists is satisfactory although some scatter is apparent, the writer tending to assign "earlier" types to the stars classed as O9 from visual estimates. Only two stars show a difference

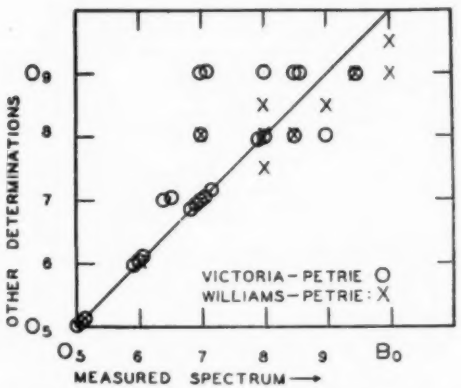


Fig. 4.—Comparison of Spectral Type determinations.

between Pearce and Petrie of more than one spectral subdivision. One of these stars, *H.D.* 57060, classed as O9 by Pearce and as O7 here, is called O7 by Miss Payne from visual estimates.[12] Miss Payne's assigned types, already referred to,[12] show almost exact agreement with those of the writer. There are eighteen stars common to the two determinations and of those only one star, *H.D.* 36861, is classified differently by as much as one spectral subdivision. Finally it may be mentioned that the three spectral

[10] *Transactions*, vol. 3, p. 167, 1928.
[11] *Hand. der Astro.*, vol. V/1, p. 68 *et seq.*, 1932.
[12] *The Stars of High Luminosity*, p. 64, 1930.

criteria suggested here agree well among themselves in indicating the spectral type; the average range is about one-half of a subdivision.

Absolute Magnitudes

It was hoped that the determination of line intensities, in addition to providing criteria for spectral classification, would show luminosity effects as well. Such effects are well established in B-type spectra where the broadening of the wings of the hydrogen lines, and to a lesser degree, of the lines of the diffuse series in helium, supply valuable information concerning intrinsic brightness. These, and other, luminosity effects, were employed successfully by Williams[7] to distinguish giant and dwarf stars and similar results were established by Rudnick.[2] In order to seek absolute magnitude effects in the spectra of O stars an attempt was made to correlate the measured line intensities with luminosity.

After the spectra had been classified the absolute magnitudes were calculated for the individual stars from measured intensities of the K line of interstellar calcium. This seems to be the only method (apart from other interstellar features) which can be used for individual objects as distant as the O stars. The K-line intensities were taken from published lists by Beals[13] and Williams[14] supplemented by some unpublished material kindly made available by Beals, and a few determinations made by the writer. The correlation between K-intensity and distance as derived by Evans[15] was employed and a space absorption of 0.8 mag. per 1000 parsecs. was assumed so that the absolute magnitudes were computed from the relations,

$$M = m - 10 - 5 \log r - 0.8\, r$$
$$r = 3w,$$

where w = intensity of K-line in equivalent angstroms
r = distance of star in kiloparsecs.

Having the absolute magnitudes it was then possible to construct correlation diagrams between line intensity and absolute magnitude. The resulting plots for H, HeI, HeII, and SiIV showed

[13] *M.N.*, vol. 94, p. 663, 1934; *M.N.*, vol. 96, p. 661, 1936.
[14] *Ap. J.*, vol. 79, p. 280, 1934.
[15] *Ap. J.*, vol. 93, p. 275, 1941.

little or no correlation between line intensity and luminosity, and so it must be concluded that spectroscopic criteria of absolute magnitude cannot be found from the material assembled in this paper. It must be remembered that the stars used in this study are all very bright and a different result might possibly have been obtained had a large range in stellar brightness been encountered. There seems to be no very obvious reason why Stark effect should not operate in the spectra of O-type stars, if the necessary atmospheric pressures obtain, but the negative result arrived at here supports conclusions of other investigators of this problem. We are then thrown back upon the use of interstellar line absorption as an index of individual brightness for the O stars.

As a by-product of the above enquiry we are able to give the mean absolute magnitudes (computed from the *K*-line intensity) for each of our spectral subdivisions: these are contained in the following tabulation,

Type	Abs. Mag.	No. Stars	Range
05	− 5.0	3	− 4.0 to − 6.0
06	− 5.0	3	− 3.8 to − 5.8
07	− 4.8	7	− 3.6 to − 5.6
08-09	− 5.1	7	− 4.0 to − 6.5

In conclusion it is pleasant to acknowledge assistance from various members of the Observatory staff in obtaining the data used in this study. Most of the spectra were obtained by Dr. C. S. Beals in connection with studies of interstellar matter and the larger part of the *K*-line intensities were taken from his measures. Some use has also been made of a few measures of stellar line intensity made by him in connection with a study of the spectral type of the star *H.D.* 193576. Miss Elizabeth Walker transformed many of the microphotometer tracings into intensity records and Mr. W. H. Stilwell analysed most of the spectra with the microphotometer and made the illustrations for the paper.

Dominion Astrophysical Observatory,
Victoria, B.C.
May, 1944.

REVIEW OF PUBLICATIONS

Rockets—The Future of Travel beyond the Stratosphere, by Willy Ley. 287 pages, 5½ x 8½ ins., 14 plates, 46 drawings. New York, The Viking Press; Toronto, Macmillan. 1944. Price $3.75.

This is a very interesting book. "The problem of space travel, and incidentally of the scientific investigation of rocket propulsion, assumed prominence not quite two decades age" (p. 4) and the author has been intimately connected with it since that time. He published two books about it (in German) in 1926 and 1928, respectively. He seems extremely well informed both on the historical and the scientific side of the subject. He has also been active in experiments on rockets and gives details of the operations in which he and his friends were engaged in Germany. He left that country early in 1935 and went to the United States via England.

The titles of the chapters are: The beginnings of an idea, The decades of the great dreams, "The rocket's red glare," Prophets with some honor, The battle of the formulae, Success, failure and politics, The meteorological rocket, The rocket into cosmic space, The spaceship, Terminal in space, Conclusion.

Then follow, Notes and addenda (20 pp.), Bibliography (8 pp.) and Index (7 pp.).

The book is written in a lively and highly attractive style. On page 137 (note) the author remarks that his English was very poor (about 1930), but it is certainly admirable in this book. One can turn to almost any page and read it with pleasure.

C.A.C.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Death of Philip Fox

The death of Philip Fox on July 21, 1944, at the age of 66, brought regret to his many friends and admirers. He was born in Manhattan, Kansas, March 7, 1878, and graduated from Kansas State College in 1897. In 1901, although he had the degrees of B.S. and M.S., he entered Dartmouth College as a senior. Here was Edwin B. Frost and he was led to choose astronomy as his life work. He received the B.A. degree in 1902 and next year went to the newly established Yerkes Observatory where he held appointment for six years, one of which he spent in Germany. At Yerkes he worked with the spectroheliograph just constructed by Hale.

In 1909 Fox became director of the Dearborn Observatory and professor of astronomy in Northwestern University, where he remained twenty years. The 18½-inch objective of the telescope is the lens with which its maker, Alvin Clark, dramatically discovered the companion to Sirius in 1862. Fox did much double-star observing and also stellar parallax determining by photography.

In 1929 Fox was chosen director of the Adler planetarium, and held this position for eight years. He set and maintained the high standard on which these institutions are conducted in the United States. He was master of ceremonies on the occasion of the opening of the Chicago World's Fair in 1933 by means of light from the star Arcturus which had started out from the star at about the time of the previous Chicago Exposition in 1893.

In 1937 he was appointed director of the Museum of Science and Industry of Chicago but for some reason not given by the management he left in 1940.

Fox was a Second Lieutenant in the Spanish war in 1898, a Major and Assistant Chief of Staff in France in 1917-19, and now was made a full Colonel, first in charge of athletics and then in radio training. He was an accomplished performer on the violin and in the art of etching. He suffered a cerebral hemorrhage and then a thrombosis and passed away within a month.

An appreciative obituary notice by Joel Stebbins is printed in *Science* for September 1, 1944.

C.A.C.

Can Anyone Explain?

Lieut. Frank L. Tabruh, 103 Gen. Hosp. U.S., writes from England:

I would like to describe a phenomenon observed here and inquire if anyone in the Society has noted it before and can explain its cause.

In the company of six other physicians, all considered dependable observers, on a chance glance at the sky I noted long narrow curved "rolls" or "bands" of what seemed to be areas of modified refractive index which passed rapidly overhead in a direct perpendicular to their lengths at a seemingly constant speed of about 3° to 5° per second. They occurred in single bands, occasionally in double ones, parallel and adajcent.

They are difficult to describe, but they appeared half-way between the zenith and horizon, between 5° and 25° in length and about ½° in width.

Time—9.00-11.00 a.m. G.C.T., Aug. 9, 1944.

Place—Lat. 51° N., Long. 1° W.

Barometer—not read, probably high.

Weather—cool, clear, light breeze from W.

Cloud formations—cirrus, few, wisp-like, sparsely scattered; below these were cumulus, occasionally cumulo-stratus.

Sun—altitude 55°, azimuth 130°, azimuth of phenomenon 250°-290°.

The bands were brief and evanescent; they appeared, moved rapidly at constant speed and vanished, seemed to travel both toward and away from the observers. Occasionally two bands met, travelling in opposite directions and passed without visible interference. The bands suggested a similarity to the bands seen in photographs of the "sound wave" at the nose and tail of a bullet in flight.

I trust someone in the Society is familiar with what I am crudely describing and would appreciate any information.

(Diagrams accompanying the description are not suitable for reproduction. Letters may be sent to this Journal—*Editor.*)

C.A.C.

Occultations of Planets by the Moon

Mr. Walter H. Haas writes as follows:

Some months ago I looked up some references to dark bands seen across the face of a planet during an occultation of it by the moon. An exhaustive and thorough search of the literature is doubtless desirable, but this thing I

must for the present forego. What I did find, however, was of much interest and is perhaps sufficiently little known to justify this letter. I gave attention to an occultation of Jupiter on Nov. 8, 1856 (*M.N.R.A.S.*, vol. 17, pp. 3-4, 1856); an occultation of Jupiter on Jan. 2, 1857 (*id.*, vol. 17, pp. 75-81 and 136-41, 1857); an occultation of Saturn on May 8, 1859 (*id.*, vol. 19, pp. 240-3 and 266, 1859); an occultation of Jupiter on Aug. 7, 1889 (*id.*, vol. 50, pp. 36-41, 1889); an occultation of Jupiter on Aug. 12, 1892 (*Astronomy and Astrophysics*, vol. 11, p. 778, 1892); and the two 1944 occultations of Jupiter.

A proper first question to ask ourselves is whether the band is objective or subjective. On this point the observations are very inconsistent. For example, in 1857 Lassell speaks of a shadowy line like the Crape Ring of Saturn; but Grove, who had seen the band in 1856, did not see it then at all. The wording of the reports is not always explicit enough. It is also somewhat unfortunate that most of the observations relate to Jupiter. Most of the observers failed to see any dark band against Saturn in 1859. With a few somewhat dubious exceptions, the band has been seen only when Jupiter is at the bright limb of the moon, being absent at the dark limb. This result raises the question of whether the band is due to contrast, and this opinion has been held by many of those who have observed it. The photographic evidence relating to its actuality is unfortunately small. Its faint presence on the original of an 1892 photograph by W. H. Pickering has been confirmed (*Sky and Telescope*, vol. 3, no. 9, pp. 20-1, 1944). I think that you will also find it inconspicuously visible on the print of a photograph by Leavens on January 13, 1944 (*id.*, vol. 3, no. 3, p. 2, 1944). Assuredly it is desirable in the future to look for the band against all planets, to attempt to photograph it, and to try to devise suitable experiments with artificial discs as a test of its reality.

The cusps of the band seen by Wates on January 13 and strikingly confirmed by the Hakes on April 30 appear to be peculiar to 1944 observations. I have found no mention of them in the old reports, and they are not shown on published drawings of those years. It appears well to suspend judgment about them and to look carefully for them in the future.

The blue colour reported by Morgan is also a rarity, it appears. The only confirmatory observations known to me are by C. F. Gramm on April 30, 1944, and by W. R. Dawes in 1857. Most of the observers say nothing of the colour of the band, probably because they thought it gray.

A number of the observers have made estimates of the width of the band. Those known to me range from 3″ to 11″ and average 5.″5. I should consider 4″ a better value, however.

A number of the observers have commented on a lack of sharpness of the edge of the band away from the lunar limb (which other edge is naturally sharp). Some describe it as gradually fading out here. There are also remarks on a semi-tranparency of the band, and one observer describes the Jovian belts as faintly visible through this band.

I am chiefly interested in the curious band discussed at such length as

possible evidence of an absorbing lunar atmosphere. Further progress in this project awaits *more systematic* and *better planned* observing. I shall be very grateful to the JOURNAL for any aid you feel disposed to give in publicizing the matter discussed.

C. A. C.

IS WASHINGTON APPROACHING LONDON?

Accompanying an earthquake there are displacements in the earth's crust, and geologists have found examples of displacements of many feet which have taken place along fault lines in past ages. Probably they did not occur suddenly. In California there is a slow crawling of the crust in the neighbourhood of the San Andreas fault which bends and buckles petroleum pipe-lines. But when one asks if there has been in modern times motion of one point on the earth's surface with respect to another, the answer is not so definite. However this question is of interest to all students of the earth and of great importance in geodesy and cartography, and many attempts have been made to obtain trustworthy evidence regarding it.

In the *Transactions* of the New York Academy of Sciences for May 1944, pp. 201-222, there is an admirable lecture by Dr. Harlan T. Stetson on "Modern Evidences of Differential Movement of Certain Points on the Earth's Surface". He remarks that from observations of the stars we can determine within a foot or two where we are north or south (latitude), and in the east and west direction (longitude) within three or four times that amount. Then he describes several investigations which have indicated definite displacements; but the measurements to be made are very small and the final results deduced are conflicting. Dr. Stetson concludes thus cautiously: "While the material I have presented may have fallen far short of what any mathematician could desire as proof, I hope I have fairly and without undue prejudice, presented evidences that exist, in such a way as to encourage a degree of open-mindedness among both astronomers and geologists on so fundamental a question as that of differential movements now going on in the earth's crust."

C. A. C.

MEETINGS OF THE SOCIETY

AT VANCOUVER

April 11, 1944.—The speaker of the evening was Dr. W. Seyer of the Department of Chemistry of the University of B.C. and his subject, "The Age of the Earth".

Dr. Seyer has examined samples of tar sands from the Fraser River and hence has gained first-hand information concerning certain radioactive processes. The speaker first discussed the radiations that come from radioactive elements, i.e., alpha, beta and gamma rays. The nature of these radiations is determined by allowing them to pass through electric and magnetic fields. It is found that alpha rays are helium nuclei, beta rays are electrons, and gamma rays radiation in the form of a wave-motion. Dr. Seyer gave an account of the main radio-active series that occur; the radioactive elements change through emission of the above menitoned rays, going through a whole series with varying half-lives, the end product apparently being lead. The half-life is simply the time taken for half the atoms of a sample to change into the next lower member of the series. It is a simple problem to determine the half-lives of elements which decay rapidly; an electroscope is suitable for the problem. More theoretical methods must be used to calculate half-lives for the elements which decay slowly.

The speaker discussed the early methods of determining the age of the earth, particularly from the concentration of salt in the sea. Lord Kelvin used the temperature gradient in the earth's crust as a means of calculating age. However, a study of radioactive ores yields the most accurate values for the age of the earth. The method is to measure the relative uranium lead content of a sample, and from the known half-lives of the various members of the series, compute the age of the sample used. Since particles are ejected during the decay of radio-active materials, and alpha particles are simply helium nuclei, the helium content of a sample is also a measure of its age.

Dr. Seyer concluded by giving various results of these methods and the agreement is quite encouraging.

WILLIAM PETRIE, *Recorder.*

AT EDMONTON

March 9, 1944.—Dr. Campbell congratulated Mr. Wates on the well-deserved winning of the Chant Medal, and read a letter from Dr. Newton extending his appreciation. Mr. Wates replied suitably.

The usual HANDBOOK talk was given by Mr. Wates. Both sides of Jupiter may be seen on successive nights if observation is good. There will be more beautiful conjunctions between Jupiter and the moon. Mercury will be in a favourable position for observation for a few days around April 13, the date of our next meeting.

The main paper of the evening was by Dr. Scott on the subject "Telescopes and their History." The invention of the telescope is shrouded by uncertainty, but Galileo was the first to make extensive use of the instrument in 1609. The Galilean telescope uses a converging objective and a diverging eyepiece, thus providing an erect image. The telescope used by Kepler, probably invented about 1620, used a converging eyepiece thus producing an inverted image. Since the magnification is equal to the ratio of the objective focal length to the eyepiece focal length it may be increased by choosing a longer focus objective, or a shorter focus eyepiece. However, if the latter is done lens defects are more important, particularly chromatic aberration. Thus the tendency was to increase the objective focal length. Huygens made an object glass with a focal length of 210 feet, but this resulted in a very unwieldly telescope. To obviate this difficulty the object glass was replaced by a paraboloidal reflecting surface. Gregory, Newton, Cassegrain, and Herschel made and used reflectors, differing only in the method used for viewing the reflected light. Most modern reflectors use both the Newtonian and Cassegrainian methods as alternatives. Of particular interest to us are the 100-inch at Mount Wilson, the 74-inch in Toronto, and the 72-inch near Victoria.

Subsequent to the work of Hall in 1733 and Dollond in 1758 on achromatism, the refracting telescope experienced a revival. There is a 36-inch one at the Lick Observatory, and a 40-inch one at the Yerkes Observatory, the largest used successfully.

Of importance in the use of telescopes is the diffraction defect. This is a consequence of the wave nature of light, and is diminished by an increase in the objective diameter. On the other hand a large diameter greatly increases image distortion due to atmospheric inhomogeneity. On this account it has even been suggested that the 200-inch telescope on Mount Palomar, when completed, may not be much better than the 100-inch. However, a third factor, the light-gathering power, is important. This is proportional to the square of the diameter, and from this point of view the 200-inch is four times as good as the 100-inch. It will thus be possible to photograph, and to obtain spectrograms of, stars which are much too faint to be reached with the 100-inch.

There were 34 members and visitors present.

April 13, 1944.—Mr. Smith was not present, so his notice of motion regarding a diploma was left over to a subsequent meeting.

On motion of Miss Malanchuk and Mr. Keeping the secretary was instructed to cast a ballot electing the following new members:

Mr. R. F. Mainwood, 10618—80 Ave., Edmonton.

Stanley V. Skrepnek, 11940—127 Ave. (Associate).

Mr. Wates gave the HANDBOOK talk as usual. On April 15 a sundial would show correct local time, i.e., 34 minutes behind standard time in Edmonton. This occurs when the mean sun and the actual sun coincide, or the equation of time is zero. The next occultation of Jupiter is during the day, and difficult to

observe. In general, however, Jupiter is well placed for observation. Mercury is visible as an evening star for a few days near the end of the month.

The meeting then adjourned to Room 311 for a showing of the slides of Mars. These arrived too late for use with Miss Malanchuk's paper on this planet, but in any case there were enough of them to require more than an hour for the showing, along with the necessary explanations. The latter were given by Mr. Wates and Dr. Campbell.

After this refreshments were served about 10 p.m. There were 27 members and visitors present.

May 11, 1944.—Application for membership was received from Miss Miriam Bowman, 9917—114 St., Edmonton. The usual motion of acceptance was made by Miss Valens and Dr. Revell, and was carried unanimously.

The Secretary showed the Copernican award sent to Mr. Nichols for his paper to the Centre last May in commemoration of the 400th anniversary of the death of Copernicus.

The HANDBOOK talk was given by Dr. Campbell. Venus is a morning star. She will be an evening star in July, but not well placed for observation till October, and will not be so spectacular as last year.

The Secretary read a letter from Mr. Wates about the use of his private telescope and observatory. He moved, seconded by Mr. MacGregor, that the Executive appoint a committee with power, to investigate (and if possible to arrange) accommodation on the University grounds. Carried.

Dr. Campbell announced the death of one of our past Presidents, and a popular member from the first season, Mr. Francis Simpson. He moved, seconded by Mr. Keeping, that the Secretary write a letter of condolence to Mrs. Simpson. Carried.

The main paper, "The Milky Way—An Orientation in Cosmology" was given by Mr. H. R. Milley.

The speaker began by giving a brief survey of the Universe and its structure as we know it. This was followed by three other sections: an historical review of important advances made in stellar and nebular research; methods used in determining the distances of stars and nebulae; the milky way system in its relation to the local nebular grouping.

In the "bird's eye view" the contents of the various bodies in the Universe were classified as cosmic dust, stars, star clusters, and nebulae. The latter are subdivided into regular and irregular types.

Historically the contributions of Galileo, Thomas Wright, Kant, Messier, the Herschels, Huggins, Henrietta Leavitt, Shapley, and Hubble were discussed. Miss Leavitt and Shapley are responsible for the period-luminosity law applicable to Cepheid variables.

A discussion of stellar magnitudes, and astronomical distance units led to an explanation of some of the methods of measuring distance such as triangulation, absolute and apparent brightness, and the variable brightness relations.

The local nebular group was illustrated by a diagram of the distribution of the component nebulae in galactic coordinates. Some of the nebular types were shown using the lantern. In particular the late type spiral nebula M 33 is very similar to our own galaxy. This Milky Way was described in more detail, as being typical, and of more special interest to us.

There were 33 members and visitors present.

May 25, 1944.—The meeting was called to order at 8.20 p.m. Mr. Keeping took the chair in the absence of President and Vice-President.

The chair announced that Dr. Campbell, Mr. Wates, and Mr. King had been named the committee to arrange the re-location of Mr. Wates' private observatory.

The HANDBOOK talk was short, most of the summer's events having been dealt with previously. There is an occultation of Mercury by the moon, but it takes place low in the sky, and is not well placed for observation. Mr. Wates went on to compare his own with other observations of bands and cusps for the two recent occultations of Jupiter. There were interesting variations among different places and different observers. The question of a possible atmosphere on the moon is involved.

The chairman then introduced the special speaker, Dr. C. S. Beals of the Dominion Astrophysical Observatory, Victoria.

The speaker brought greetings to the Edmonton Centre from Dr. Pearce and from Jean McDonald. He also congratulated Edmonton on having a new observatory and a fine telescope.

The subject of his address was: "Inter-stellar Matter as a Problem in Laboratory Physics." The existence of tenuous matter in the spaces between the stars has been known for 50 years, and has been studied by many astronomers in that time. There are two main classes of this matter,—solid dust particles, and very low density gas.

Summary of the evidence for dust particles:—Photographs of the sky show dark patches, and also bright patches having the same spectrum as the star which shines through them. There are brightness discrepancies between stars of the same type, seemingly due to obscuration. Calculation of the obscuration to be expected from dust and gas favours dust as the cause. Spectrograms show that some very hot stars seem a bit redder due to absorption and scattering by this dust, and a calculation of average size can be made. The value is about ten millionths of a centimetre. Observations of meteors coming from outside the solar system make possible an estimate of the relative numbers of particles having sizes a little different from this average.

Summary of the evidence for gas:—Bright nebulae show line spectra similar to laboratory gas discharge (or neon sign). Binary stars show changes in their lines due to the Doppler effect, but the absorption lines due to inter-stellar matter show no change. The Doppler effect applied to these lines shows only solar system motion, and the effects of galactic rotation. At these low pres-

sures even molecules of gas can produce sharp lines. What lack of sharpness occurs is probably due to the presence of some solid particles.

A hearty round of applause was given to the speaker as the meeting adjourned in time for him to catch his train. There were 40 members and visitors present.

E. H. GOWAN, *Honorary Secretary.*

AT TORONTO

November 9, 1943.—The Society met at 8.00 p.m. in the McLennan Laboratory, University of Toronto; Miss R. J. Northcott in the chair.

Mr. George E. Campbell of the Society's Hamilton Centre spoke on "Astronomical Paradoxes." Some of those he described were:

"Some large bodies in the universe are harder to see the closer you approach them. When you get inside them you cannot see them at all."—The diffuse nebulae which fill all space but are without regular dimensions are much rarer than the most perfect laboratory vacuum. They get thinner and thinner down to one atom per cubic inch and then build up again to another diffuse nebula. Our stellar system is inside one of them but we cannot see it.

"How can we get something for nothing?"—We get light from the diffuse nebulae but they have no light of their own, being dependent entirely upon nearby stars. No matter how close we could approach, the light would become no brighter. Any unit area of the nebular surface would still be just as faint as if seen from a much greater distance.

"We can discover an object without seeing it."—Example: Discovery of the planets Neptune and Pluto by mathematical computation.

"We can see an object without discovering it."—Example: After Pluto had been located and observed, it was found that the planet had been photographed (seen) many times before it was discovered.

"We can observe an object without seeing it."—Example: An astronomer may have taken part in many successful eclipse expeditions and made plenty of observations, but always in the dark room at the end of the telescopic camera. Actually such an astronomer might never have seen a total eclipse with his own eyes.

"What in the universe goes steadily forward but retraces its steps?"—Example: A superior planet retrograding as the earth overtakes and passes it.

"What continually falls to earth but never arrives?"—The moon is continually "falling" under gravitational pull but its orbital velocity keeps it in its course. Or similarly, the earth "falling" towards the sun.

"Can we ride a sunbeam?"—The heaviest part of the human body is calcium which is better able to "ride" sunbeams than any other element. The chromosphere is not attached to the sun like the earth's atmosphere to our planet, but floats freely above it, pushed out by radiation. It so happens that the sun is rich in radiation which will excite the calcium atom and deficient in radiation that will ionize it.

Mr. Tracy D. Waring read a copy of a letter sent to Dr. C. A. Chant on behalf of the officers and members of the Centre expressing sympathy in the death of Mrs. Chant, and Dr. Chant's reply which read, in part: "Please convey to the members of the Centre my sincere thanks for their kind message. . . . Mrs. Chant was always deeply interested in the Toronto Centre and regretted that latterly she had not been able to attend any of the meetings."

Miss Ruth Northcott presented the second in the series of short papers on "Fundamentals of Astronomy," in which she dealt with the various kinds of time used in astronomy. Brief excerpts follow:

The rotation of the earth on its axis provides the fundamental means of measuring time. This is more accurate than any clock yet constructed although variations of the order of a thousandth of a second have been detected from astronomical observations of eclipses, etc.

Two things are necessary for telling time: 1, a time reckoner, the hour hand; 2, a reference line, taken as the earth's meridian. Three kinds of time are in use, defined by three different time reckoners: Sidereal time, using the vernal equinox; Apparent Solar time, using the apparent or true sun, and Mean Solar time, using a fictitious "mean sun."

Sidereal time is local and due to the apparent motion of the sun among the stars during the year. The vernal equinox crosses the meridian about four minutes earlier each day, at apparent noon about March 21 and at midnight about September 23.

Apparent Solar time is recorded by a sundial. It is local and the days vary in length because the sun apparently moves non-uniformly along the ecliptic.

Mean Solar time is defined by the "mean sun" which moves uniformly along the equator, completing a revolution in the same time as the real sun. The length of a mean solar day is the average apparent solar day. Mean time is local, but is uniform and brings the sun to the meridian close to noon each day. For convenience in everyday life Standard time is now used.

November 23, 1943.—The Society met at 8.00 p.m. in the McLennan Laboratory, University of Toronto; Miss R. J. Northcott in the chair.

One candidate was elected to membership in the Society, viz:

L.A.C. Robert W. Baker, 151 The Kingsway, Toronto.

Mr. S. G. Ellis of the department of physics, University of Toronto, addressed the Society on "Meteorology." Dealing first with the earth's atmosphere and the velocity of escape of gases from the earth and other planets, he pointed out that most of the gases in the moon's atmosphere, if our satellite had one, would escape in less than a week. Mars, he explained, is unlikely to have an atmosphere much like the earth's, but there is a good chance that some of the heavier gases remain.

He explained how air currents might be expected to operate in various theoretical atmospheres: on a planet entirely surrounded by water, a planet with equal temperature at equator and poles, etc. Because of unequal distribu-

tion of land and water surfaces, inclination of the earth's axis to the sun's rays, and many other factors, it was not possible in physics to work out the behaviour of the large air masses in the earth's atmosphere with exactness.

Passing on to the formation of clouds when cold and warm air masses meet, Mr. Ellis described how clouds with flat bases at about the same level tower upward into various shapes and to different heights due to vertical air currents. Hail formed in the upper parts of such clouds becomes much larger as it falls through the clouds than hailstones formed at the bottom of similar clouds. This accounts for hail of very different sizes falling at the same time. Large rain drops fall more *slowly* than small ones, he added.

Vertical air currents are used by glider pilots who keep a watch for cloud formations indicating rising air and then "sit" on the upward currents, rising as high as possible before gliding along to the next one. A glider falls an average of five feet per second, but if the pilot can find an air current rising at 20 feet per second he can achieve a net increase in height of 15 feet, better than a motor-powered airplane can do, Mr. Ellis said. Birds also use such currents and often float for hours with little effort wasted in beating their wings.

The history of meteorology as a science began about the time when Torricelli invented the barometer, 300 years ago, but few records were kept and no attempt was made at scientific weather forecasting. Benjamin Franklin was possibly the first to realize that storms were not purely local phenomena but that they passed in wide paths over large areas of the globe. Invention of the telegraph and exchange of reports on weather conditions, at first between a limited number of stations in local regions, but now internationally, led to the advances which have resulted in to-day's scientific meteorology. During the last war when most nations were withholding their meteorological knowledge as war secrets, Norway, as a neutral country, brought the biggest advance to weather science in the development of the "polar front" theory of atmospheric circulation.

Miss R. J. Northcott presented the third paper on "Fundamentals of Astronomy" in which she dealt with the planets and with the useful and interesting material on the solar system contained in the Society's OBSERVER'S HANDBOOK. She defined the various planetary configurations describing the position of a planet with respect to the sun: elongation, conjunction, opposition, and quadrature; and explained briefly the laws of planetary motion, retrogression of planets and the elements by which the motion of a planet may be defined. In conclusion she referred to the tables giving the configurations for Jupiter's satellites and explained how they are interpreted.

A Nominating Committee to recommend Officers and Council of the Centre for 1944 being required, it was moved by Mr. C. A. Crook and seconded by Mr. T. H. Mason that this committee comprise Dr. D. W. Best as chairman, together with Mr. J. R. Collins and Mr. E. J. A. Kennedy. Carried.

FREDERIC L. TROYER, *Recorder.*

The Royal Astronomical Society of Canada

OFFICERS FOR 1944

Honorary President—The Honourable Geo. A. Drew, Prime Minister and Minister of Education for the Province of Ontario
President—A. Vibert Douglas, M.B.E., Ph.D., Kingston
First Vice-President—A. E. Johns, Ph.D., Hamilton
Second Vice-President—H. Boyd Brydon, Victoria
General Secretary—E. J. A. Kennedy, 198 College St., Toronto
General Treasurer—J. H. Horning, M.A., 198 College St., Toronto
Recorder—H. W. Barker, Toronto *Librarian*—F/L. P. M. Millman, Ph.D.
Council—C. S. Beals, Ph.D., Victoria; S. C. Brown, Toronto; G. E. Campbell, M.A., Hamilton; J. W. Campbell, Ph.D., Edmonton; W. G. Colgrove, M.A., B.D., London; DeLisle Garneau, Montreal; Mrs. F. Shirley Jones, Ph.D., Toronto; Mgr. T. W. Morton, Winnipeg; Paul H. Nadeau, Quebec; Andrew Thomson, Ph.D., Toronto; M. M. Thomson, Ottawa; G. M. Volkoff, Ph.D., Vancouver; and Past Presidents—J. A. Pearce, Ph.D. and F. S. Hogg, Ph.D., also the presiding officer of each Centre.

TORONTO CENTRE

Honorary Chairman—C. A. Chant, LL.D. *Chairman*—Miss Ruth Northcott, M.A.
Vice-Chairman—H. W. Barker *Secretary*—Tracy D. Waring, 44 Rosepark Drive
Treasurer—T. H. Mason *Recorder*—F. L. Troyer *Curator*—R. S. Duncan
Council—D. S. Ainslie, Ph.D.; A. R. Clute, K.C.; H. Duncalfe; Miss E. M. Fuller; L. Gilchrist, Ph.D.; S/L. J. F. Heard, Ph.D.; F. S. Hogg, Ph.D.; J. H. Horning, M.A.; F/L. P. M. Millman, Ph.D.; W. T. Patterson, R.O.; Rev. C. H. Shortt; R. K. Young, Ph.D.; and Past Chairmen—J. R. Collins, E. J. A. Kennedy, S. C. Brown and Dr. D. W. Best.

OTTAWA CENTRE

Honorary President—F. W. Matley, Esq. *President*—T. L. Tanton, Ph.D.
First Vice-President—Hoyes Lloyd, M.A. *Second Vice-President*—F/O. Malcolm M. Thomson
Secretary—F. W. Matley, 127 Metcalfe St. *Treasurer*—A. C. Steedman, B.A.
Council—H. M. Bradley; R. G. Madill, B.A.; W. S. McClenahan, B.A.; R. J. McDiarmid, Ph.D.; C. B. Reilly, K. C.; and the Past Presidents—Miss M. S. Burland, B.A.; J. McLeish, B.A.; A. H. Miller, M.A.

HAMILTON CENTRE

Honorary President—W. T. Goddard *President*—W. T. Stewart, B.A.
Vice-President—Rev. E. W. Maunsell
Secretary-Treasurer—J. R. Graham, 64 Blake St. *Curator*—T. H. Wingham, B.A.Sc.
Council—F. H. Butcher, B.A.; T. M. Norton; Dr. Wm. Findlay; Dr. A. E. Johns; G. E. Campbell, M.A.; W. S. Mallory, M.A.; F. Sisman; G. D. Burns; F. Schneider, H. B. Fox.

WINNIPEG CENTRE

Honorary President—Rt. Rev. T. W. Morton *President*—L. T. S. Norris-Elye
First Vice-President—Miss O. A. Armstrong *Second Vice-President*—W. P. Johnson
Secretary—Miss M. F. Watterson, 612 Toronto General Trusts Building
Treasurer—Miss Shirley Colquette *Press Secretary*—L. W. Koser
Council—R. D. Colquette; L. J. Crocker; C. D. Dorsett; V. C. Jones (Past Pres.); Mrs. J. Morris; H. E. Riter; R. A. Storch; and Prof. L. A. H. Warren.

MONTREAL CENTRE

Honorary President—Mgr. C. P. Chcquette
President—D. P. Gillmor, K.C. *Vice-President*—G. Harper Hall
Secretary—Henry F. Hall, 1441 Drummond St.
Treasurer—F. J. Dekinder *Recorder*—Miss I. K. Williamson
Librarian—J. W. Duffie *Chairman Telescope Committee*—DeLisle Garneau
Council—Dr. A. N. Shaw; Dr. W. Bruce Ross; F. P. Morgan; J. E. Guimont; E. R. Paterson; C. M. Good and D. E. Douglas.

VICTORIA CENTRE

Honorary President—R. Peters *President*—O. M. Prentice
First Vice-President—A. McKellar, Ph.D. *Second Vice-President*—K. O. Wright, Ph.D.
Secretary-Treasurer—Mrs. M. V. Yarwood, 986 Wilmer St., Victoria
Recorder—Mrs. W. Stilwell *Director Telescope-Making*—W. Hobday
Librarian—Miss Y. Langworthy
Council—Dr. W. P. Walker; J. Moulson; W. Stilwell; H. D. Day; M. Trueman; Dr. J. Stevenson.

LONDON CENTRE

Honorary President—Dr. H. R. Kingston
President—Dr. G. R. Magee *Vice-President*—Rev. M. E. Conron
Secretary-Treasurer—R. H. Cole, University of Western Ontario
Council—A. Emsley; Miss C. Chapman; R. E. Winters; Mrs. A. Emsley; Dr. G. W. Hopperd.

VANCOUVER CENTRE

Honorary President—Dr. J. A. Pearce, Dominion Astrophysical Observatory
President—N. D. B. Phillips *Vice-President*—H. D. Smith, Ph.D.
Secretary—Norman Barton, M.A., University of British Columbia
Recorder—W. Petrie, Ph.D. *Treasurer*—F. G. Berton
Council—C. Jorgensen; Mrs. C. A. Rogers; Mrs. L. Anderson; P. H. Newton; M. A. McGrath; G. T. Gilpin; A. Outram; J. G. Hooley, Ph.D.

(*Continued at bottom of next page*)

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA
1890-1944

The Society was incorporated in 1890 under the name of The Astronomical and Physical Society of Toronto, and assumed its present name in 1903.

For many years the Toronto organization existed alone, but now the Society is national in extent, having active Centres in Montreal and Quebec, P.Q.; Ottawa, Toronto, Hamilton and London, Ontario.; Winnipeg, Man.; Edmonton, Alta.; Vancouver and Victoria, B.C. As well as about 800 members of these Canadian Centres, there are over 200 members not attached to any Centre, mostly resident in other nations, while some 300 additional institutions or persons are on the regular mailing list for our publications.

The Society publishes a monthly JOURNAL containing about 500 pages and a yearly OBSERVER'S HANDBOOK of 80 pages. Single copies of the JOURNAL or HANDBOOK are 25 cents, postpaid. In quantities of 10 or more copies, the price is 20 cents a copy.

Membership is open to anyone interested in astronomy. Annual dues, $2.00; life membership, $25.00. Publications are sent free to all members or may be subscribed for separately. Applications for membership or publications may be made to the General Secretary, 198 College St., Toronto.

The Society has for Sale:

Reprinted from the JOURNAL of the Royal Astronomical Society, 1936-1943.

The Physical State of the Upper Atmosphere, (revised 1941) by B. Haurwitz, 96 pages; Price 75 cents postpaid.

General Instructions for Meteor Observing, (revised 1940) by Peter M. Millman, 24 pages; Price 15 cents postpaid.

A. H. Young's Simple Mounting for the 6-inch Reflector, by H. Boyd Brydon, 16 pages; Price 10 cents postpaid.

The Visual Photometry of Variable Stars, by H. Boyd Brydon, 64 pages; Price 50 cents postpaid.

A Yoke Mounting for the Six-inch Telescope, by H. Boyd Brydon, 8 pages; Price 10 cents postpaid.

Does Anything Ever Happen on the Moon? by W. H. Haas, 76 pages, 5 plates; Price 60 cents postpaid.

Setting Up and Adjusting the Equatorial Reflecting Telescope by H. Boyd Brydon, 25 pages; Price 25 cents postpaid.

In quantities of ten or more copies, a discount of 20 per cent will be allowed. Send Money Order to 198 College St., Toronto.

(*Continued from previous page*)

EDMONTON CENTRE

Honorary President—J. W. CAMPBELL, PH.D. *President*—G. W. ROBERTSON
Vice-President—A. J. COOK *Secretary*—E H. GOWAN
Treasurer—MISS A. M. P. SMITH *Librarian*—E. S. KEEPING
Council—J. R. TUCK; C. G. WATES; W. E. MJOLSNESS; M. WIMAN; F. C. BLOWER.

QUEBEC CENTRE

Honorary President—GERMAIN BEAULIEU *President*—JEAN CHARLES MAGNAN
Vice-President and Treasurer—LUCIEN POULIOT, C.G.A.
Secretary and Director of the Observatory—PAUL H. NADEAU, 275 St. Cyrille St.
Council—ABBE ROSARIO BENOIT; ABBE EMILIEN GAUTHIER; LIONEL LEMIEUX; HENRI PAUL KOENIG, M.Sc.; M. LOUIS CARRIER, I.C., Director of the Cercle Leon Faucault; LUCIEN MASSE, D.Sc.; ALBERIC BOIVIN.